GE Astro Space Division
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Definition and Preliminary Design of the

LAWS

Laser Atmospheric Wind Sounder

PHASE I
FINAL REPORT VOLUME III

PROGRAM COST ESTIMATES

Date: 3/26/90
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Contract Number: NAS8-37589

GE Astro Space
Hughes Danbury
Spectra Technology

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This document is Volume III of the LAWS Study (Phase I) Final Report and presents our cost estimates for Phase C/D of the LAWS program. The information contained herein provides a framework for cost, budget and program planning estimates for LAWS.

Volume III is organized in three sections. Section I details the approach taken to produce the cost figures, including our assumptions regarding the schedule for phase C/D and the methodology and rationale for costing the various work breakdown structure (WBS) elements.

Section 2.0 shows a breakdown of the cost by WBS element, with the cost divided into non-recurring and recurring expenditures. Note throughout this volume the cost is given in 1990 dollars, with bottom line totals also expressed in 1988 dollars ($1(88)= 0.93$1(90)).

Section 3.0 shows a breakdown of the cost by year.

The WBS and WBS dictionary are included as an attachment to this report.

1.0 Costing Approach, Methodology and Rationale

The cost data presented in this volume have been developed assuming the hardware configuration detailed in Volume II of the LAWS Final Report (Phase I). The major hardware subsystems are:

- a laser subsystem comprising a 10 J, 20 Hz self-sustained laser transmitter capable of firing on command, and a local oscillator consisting of a frequency stabilized waveguide laser;
- an optical subsystem comprising a 1.5 m aperture telescope, conically scanned about nadir, mixing optics and an alignment and controls subsystem;
- a receiver subsystem comprising a circularly symmetric array detector, with a single central element and four surrounding elements.

These major hardware elements, together with supporting subsystems are integrated to the spacecraft via a mechanical support structure which consists of graphite epoxy tubes with titanium end-fittings from our UARS heritage.

The laser, optics and structure are large and a major cost driver will be the number of models of each which are necessary to complete the program. We have assumed that, as the subsystem which consists of the most new technology, the laser should go through the full development cycle of an engineering, qualification and a flight model. The optics subsystem has been assumed protoflight. We have assumed two models for the structure an engineering/qualification model and a flight model.

The costing has been performed assuming the Japanese Polar Orbiting Platform (JPOP) launched by an expendable launch vehicle. The cooling has been assumed to be handled by the platform as is the case with the US Space Station Polar Platforms.

1.1 Schedule and Financial Assumptions

We have assumed a 4.5 year schedule for LAWS (see Figure 1-1). The schedule is to instrument delivery, and excludes spacecraft integration, launch and flight operations. Detailed schedules for each of the major program elements are given in the Appendix. The cost estimate is given in GFY90 Dollars with a separate figure given for GFY88 Dollars ($88 = 0.93 $90). Recurring and non-recurring costs are broken out.

1.2 Methodology and Rationale

A WBS for the LAWS program was developed (Figure 1-2), with the major subsystems broken down to their major assemblies (level 6). This WBS is presented together with a WBS Dictionary as an attachment to this report. To cost the elements of the WBS a variety of approaches was used depending on the applicability.

A number of the WBS elements were costed based on our experience with similar programs, in particular UARS. Where similar programs were invoked we made necessary adjustments for differences between the programs including perceived levels of complexity and scope.

A parametric analysis and "bottoms-up" approach was used for the telescope using the large existing Hughes Danbury data base.

A cost model developed at Spectra Technology, and based on their experience with large CO2 laser programs, was used for the laser.

The structure was costed based on our experience on similar programs, in particular UARS.

Other elements of the WBS were costed using a "bottoms-up" approach where possible. This approach was also used as a cross-check against other costing methods where we were able to do so.

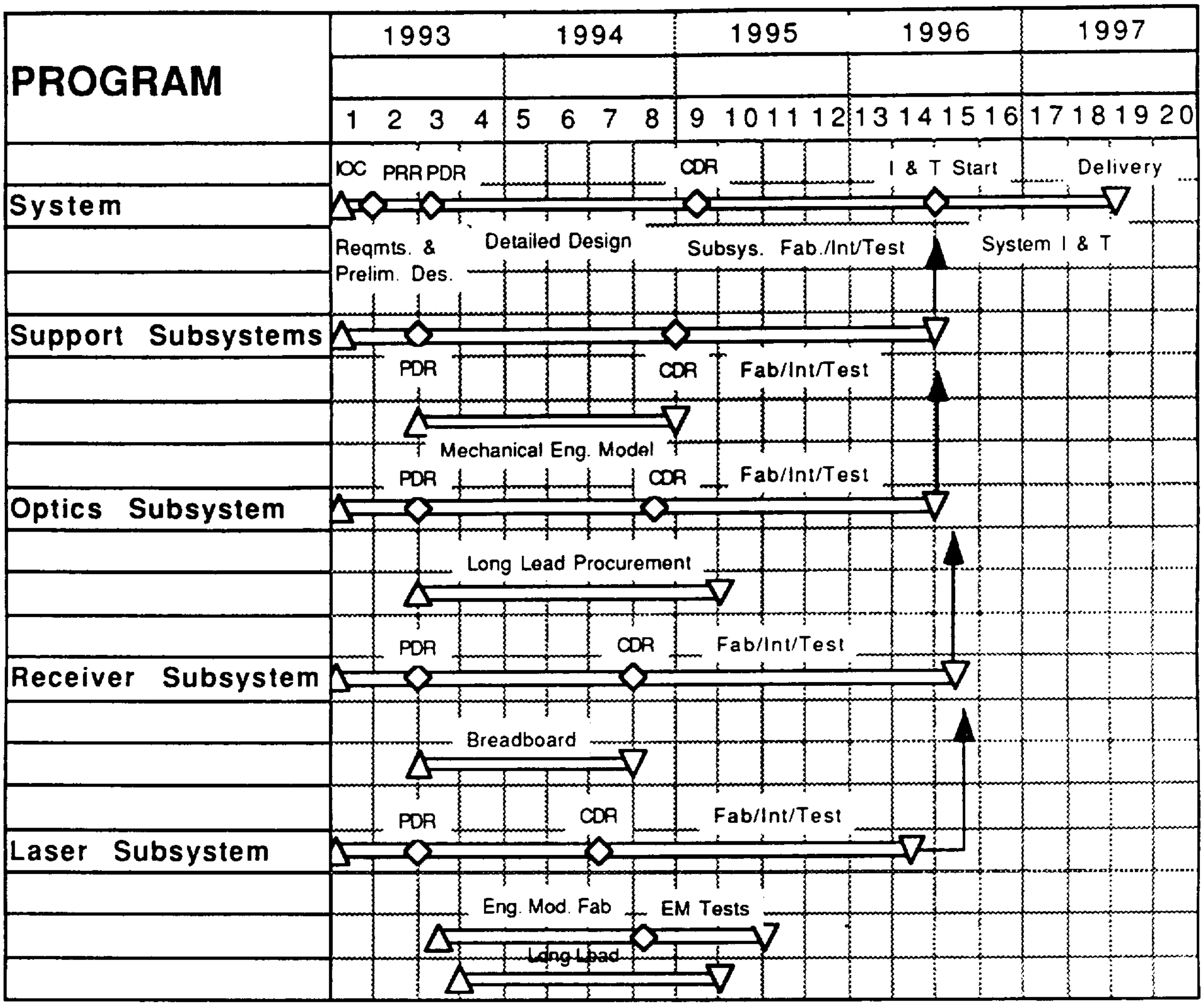


Figure 1-1 LAWS Phase C/D Program Schedule

Section 2 gives the basis of estimate for each WBS element.

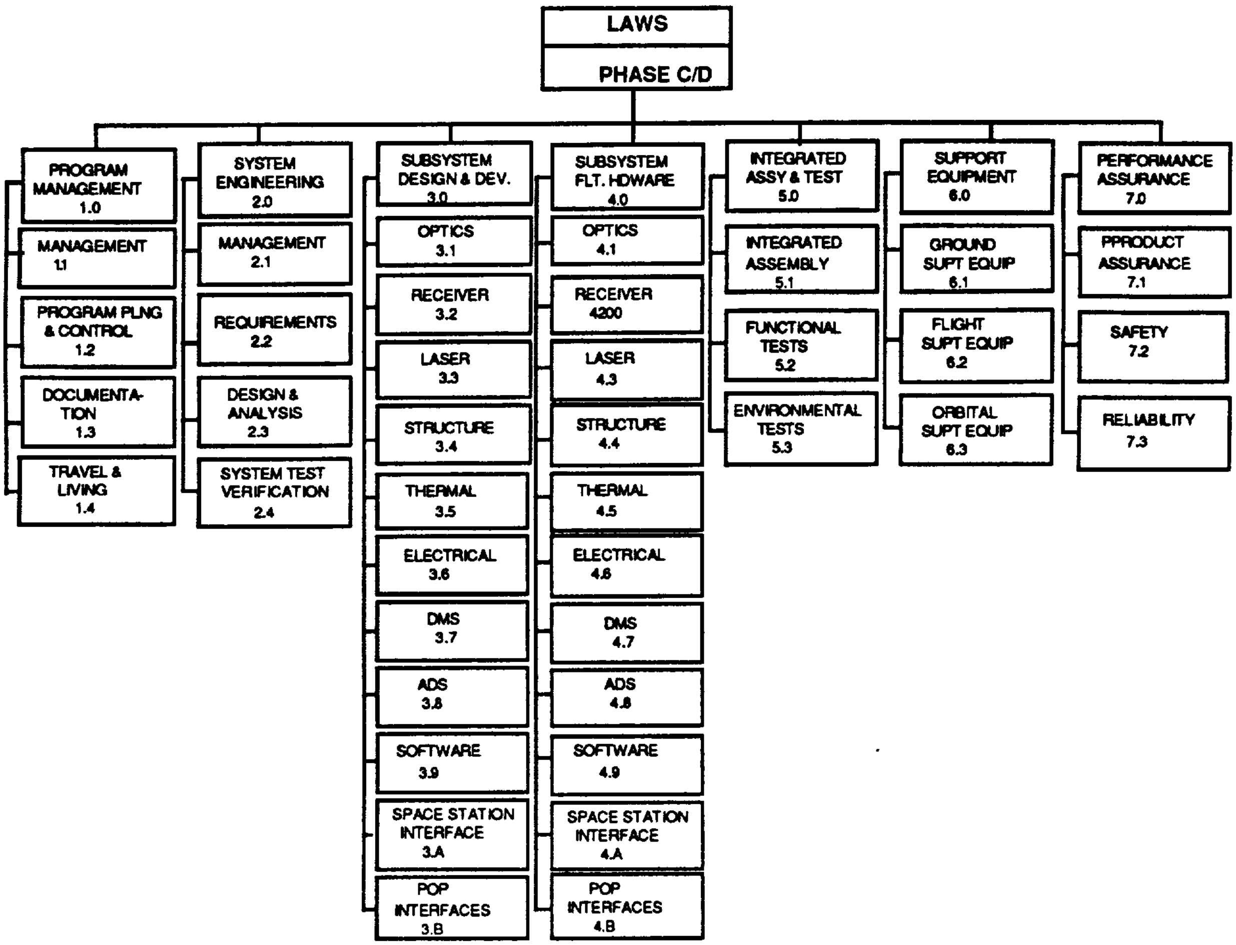


Figure 1-2 LAWS Phase C/D Work Breakdown Structure

2.0 COST ESTIMATE BY WBS ELEMENT

The methods we used to estimate the costs of each WBS element are given in Figure 2-1. Our cost estimates for each WBS element are given in Figure 2-2 divided into recurring and non-recurring costs.

1.0		PROGRAM MANAGEMENT	SIMILAR PROGRAMS
2.0		SYSTEM ENGINEERING	SIMILAR PROGRAMS
3.0/4.0		SUBSYSTEMS	
	.1	Optics	PARAMETRIC/BOTTOMS UP
	.2	Receiver	BOTTOMS UP
	.3	Laser	COST MODEL
	.4	Structure	SIMILAR PROGRAMS
	.5	Thermal	SIMILAR PROGRAMS
	.6	Electrical	SIMILAR PROGRAMS
	.7	Data System	POP HARDWARE
	.8	ADS	SIMILAR HARDWARE
	.9	Software	SIMILAR PROGRAMS
	.10	Platform Interface	SIMILAR PROGRAMS
5.0		INTEGRATED TEST AND ASSEMBLY	SIMILAR PROGRAMS
6.0		SUPPORT EQUIPMENT	SIMILAR PROGRAMS
7.0		PERFORMANCE ASSURANCE	SIMILAR PROGRAMS

Figure 2-1 LAWS Phase C/D Cost - Basis of Estimate

WBS	$M(FY90)		
	Non-Rec.	Rec.	Total
1.0 Program Management	**7.4**	**7.3**	**14.7**
1.1 Management	4.0	4.0	8.0
1.2 Program Plng and Control	1.6	1.5	3.1
1.3 Documentation	0.9	0.9	1.8
1.4 Travel and Living	0.9	0.9	1.8
2.0 Systems Engineering	**5.8**	**1.2**	**7.0**
2.1 Management	0.6	0.6	1.2
2.2 Requirements	1.0	0.0	1.0
2.3 Design and Analysis	4.1	0.5	4.6
2.4 Sys. Test & Verification	0.1	0.1	0.2
3.0 Subsystem Design & Developmt.	**75.6**		**75.6**
4.0 Subsystem Flight Hardware		**74.0**	**74.0**
.1 Optics	36.3	45.0	81.3
.2 Receiver	2.0	4.0	6.0
.3 Laser	26.3	17.4	43.7
.4 Structure	4.8	2.7	7.5
.5 Thermal	1.0	0.5	1.5
.6 Electrical	2.5	2.0	4.5
.7 DMS	1.2	1.4	2.6
.8 ADS	0.1	0.3	0.4
.9 Software	1.3	0.2	1.5
.B POP Interfaces	0.1	0.5	0.6
5.0 Integrated Test & Assembly	**1.6**	**3.6**	**5.2**
5.1 Integrated Assembly	1.0	2.4	3.4
5.2 Functional Tests	0.2	0.4	0.6
5.3 Environmental Tests	0.4	0.8	1.2
6.0 Support Equipment	**2.7**	**0.1**	**2.8**
6.1 Ground Support Equipment	2.4	0.1	2.5
6.2 Flight Support Equipment	0.3	0.0	0.3
7.0 Performance Assurance	**0.9**	**2.5**	**3.4**
7.1 Product Assurance	0.5	2.4	2.9
7.2 Safety	0.2	0.1	0.3
7.3 Reliability	0.2	0.0	0.2
Total Through Fee			
FY90	**94.0**	**88.7**	**182.7**
FY88(93%)	**87.4**	**82.5**	**169.9**

Figure 2-2 LAWS Phase C/D Cost Estimates - Non-recurring/Recurring

3.0 TOTAL PROGRAM FUNDING SCHEDULE

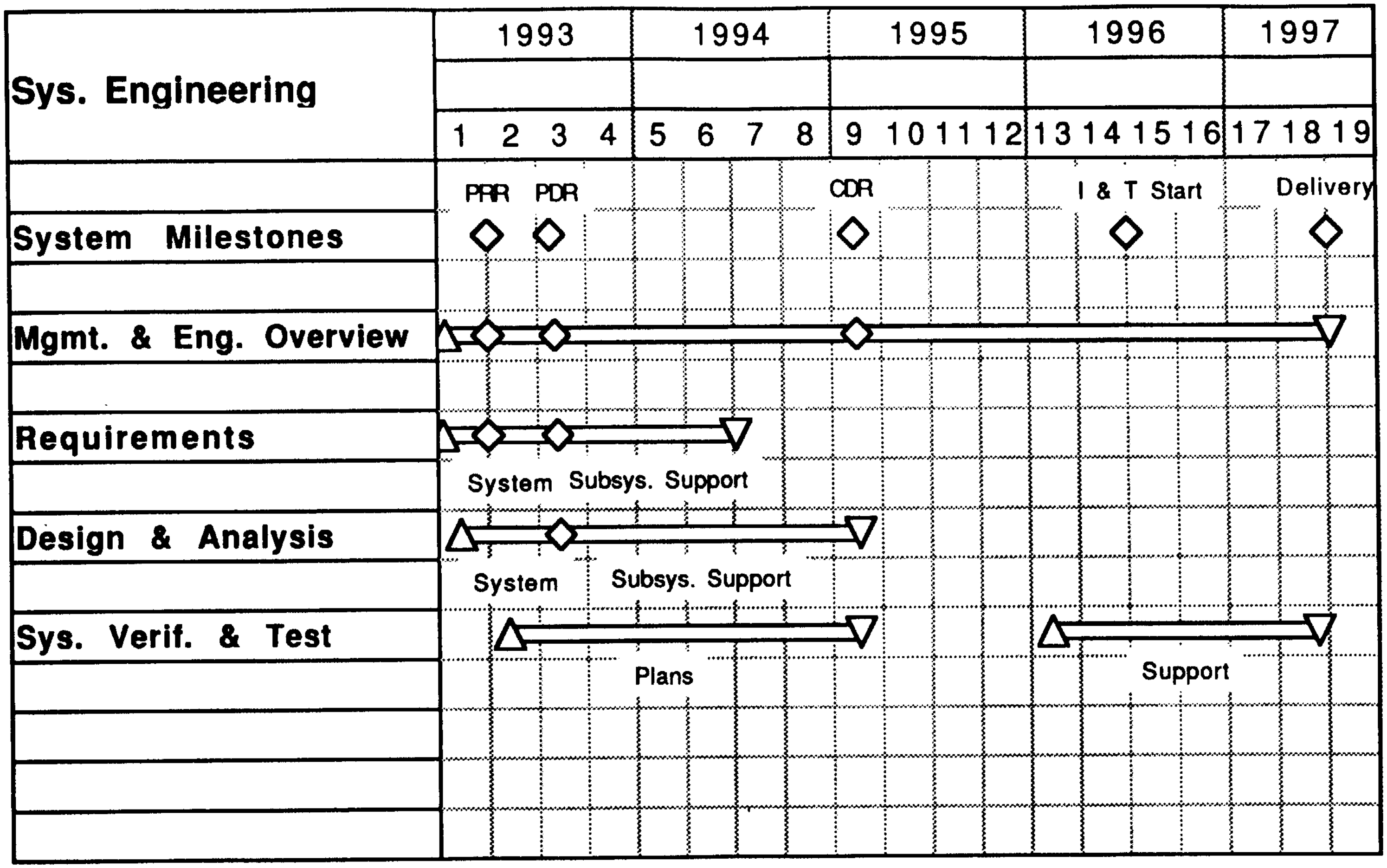
The time phased cost estimate for the 4.5 years of the program is shown in Figure 3-1. The time phasing was developed based on our experience with similar programs.

WBS	$ M					
	Year 1	Year 2	Year 3	Year 4	Year 5	Total
1.0 Program Management	3.2	3.3	3.2	3.2	1.8	14.7
2.0 Systems Engineering	3.3	2.4	0.7	0.3	0.3	7.0
3&4 Subsystem Flight Hardware	25.3	51.8	48.9	21.4	2.2	149.6
.1 Optics	14.6	29.3	23.6	13.0	0.8	81.3
.2 Receiver	1.2	1.5	1.8	1.2	0.3	6.0
.3 Laser	6.1	15.7	17.9	3.6	0.4	43.7
.4 Structure	1.4	2.2	2.2	1.5	0.2	7.5
.5 Thermal	0.3	0.5	0.4	0.2	0.1	1.5
.6 Electrical	0.8	1.3	1.4	0.9	0.1	4.5
.7 DMS	0.4	0.7	0.9	0.5	0.1	2.6
.8 ADS	0.1	0.1	0.1	0.1	0.0	0.4
.9 Software	0.3	0.4	0.4	0.3	0.1	1.5
.B POP Interfaces	0.1	0.1	0.2	0.1	0.1	0.6
5.0 Integrated Test & Assembly	0.2	0.2	0.7	2.9	1.3	5.2
6.0 Support Equipment	0.4	0.7	1.0	0.6	0.1	2.8
7.0 Performance Assurance	0.5	0.6	1.1	1.0	0.2	3.4
Total Through Fee						
FY90	32.9	59.0	55.6	29.4	5.9	182.7
FY88(93%)	30.6	54.8	51.7	27.3	5.5	169.9

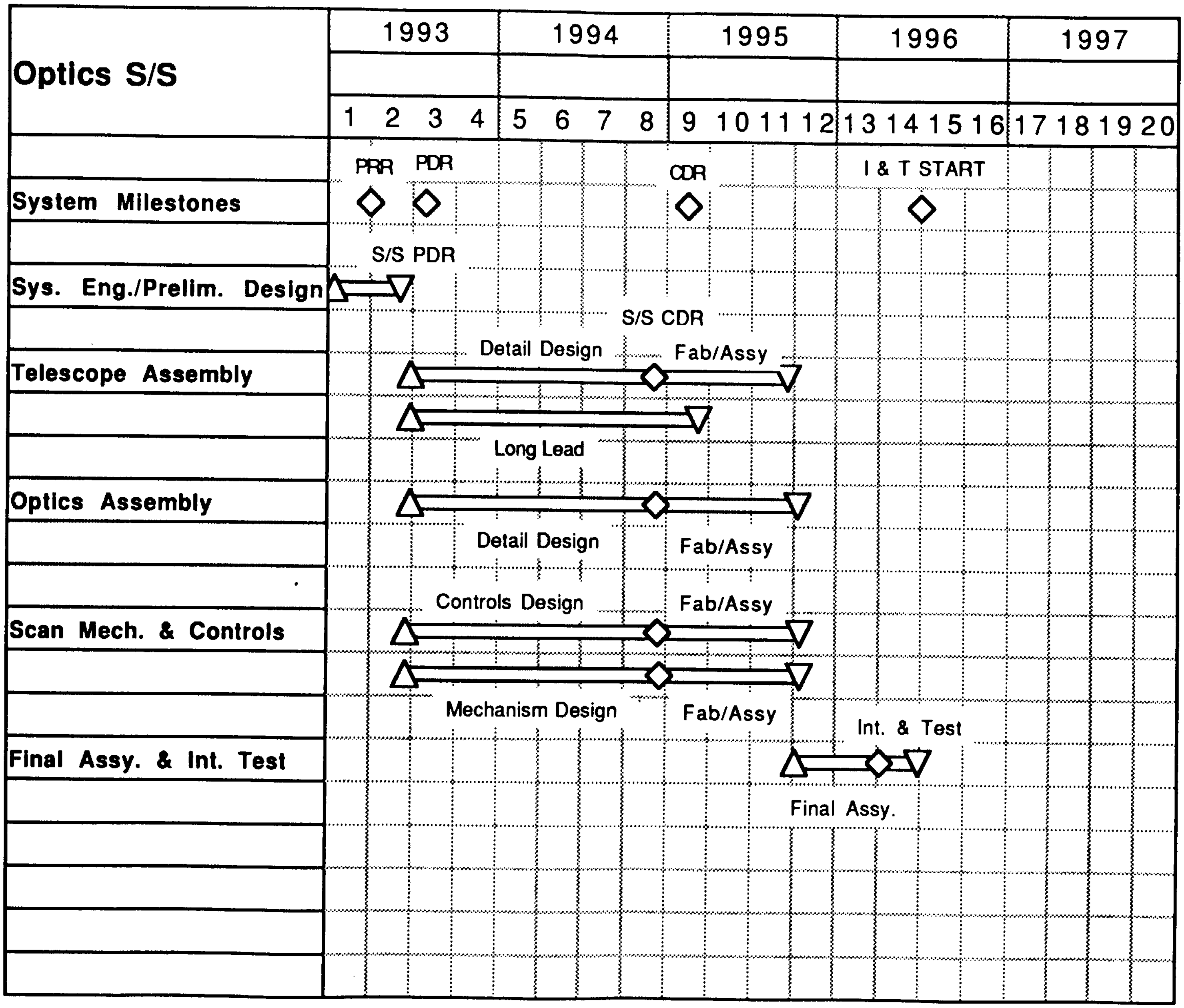
Figure 3-1 LAWS Phase C/D Estimated Time Phased Costs

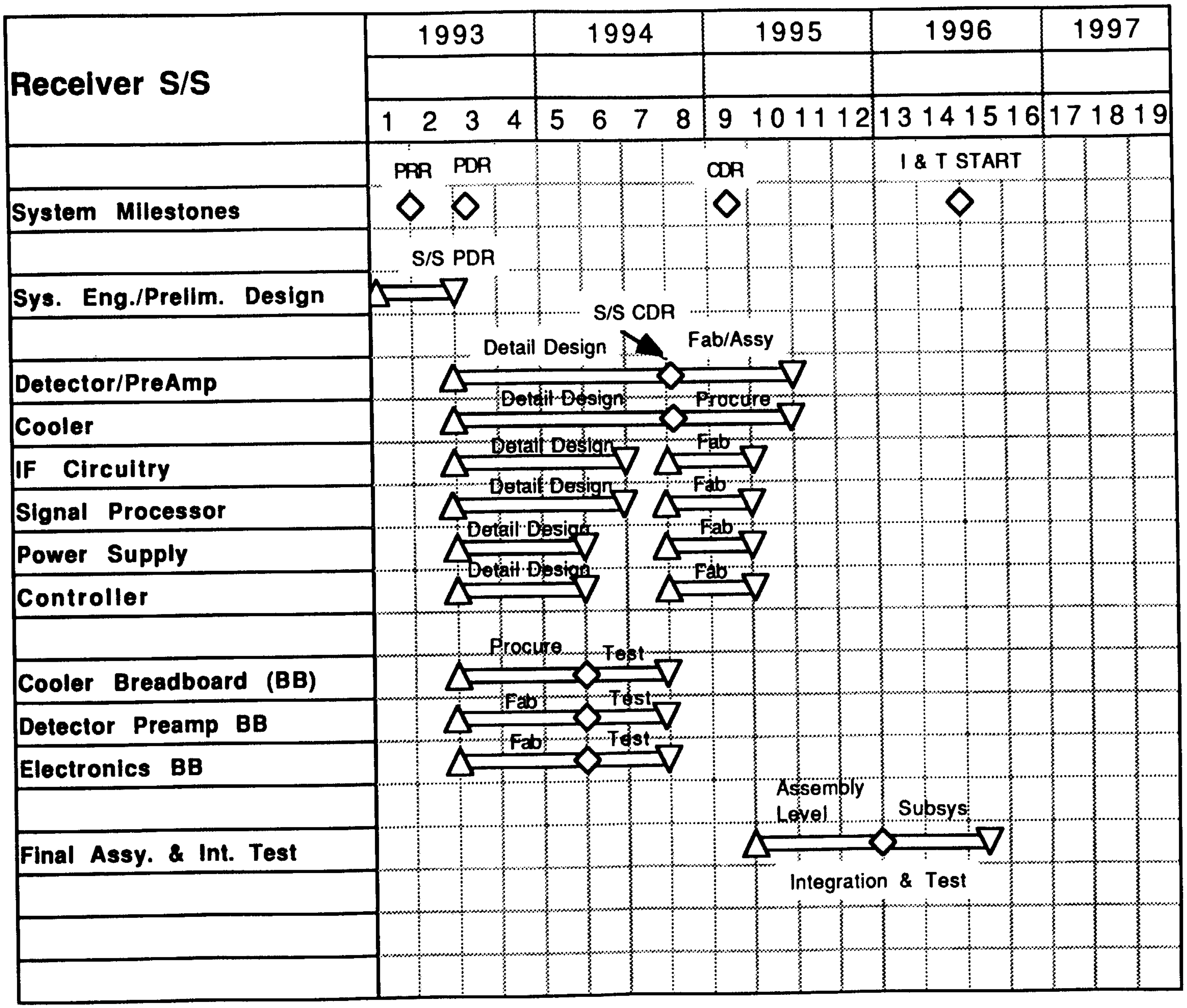
APPENDIX

Schedules for Major Program Elements

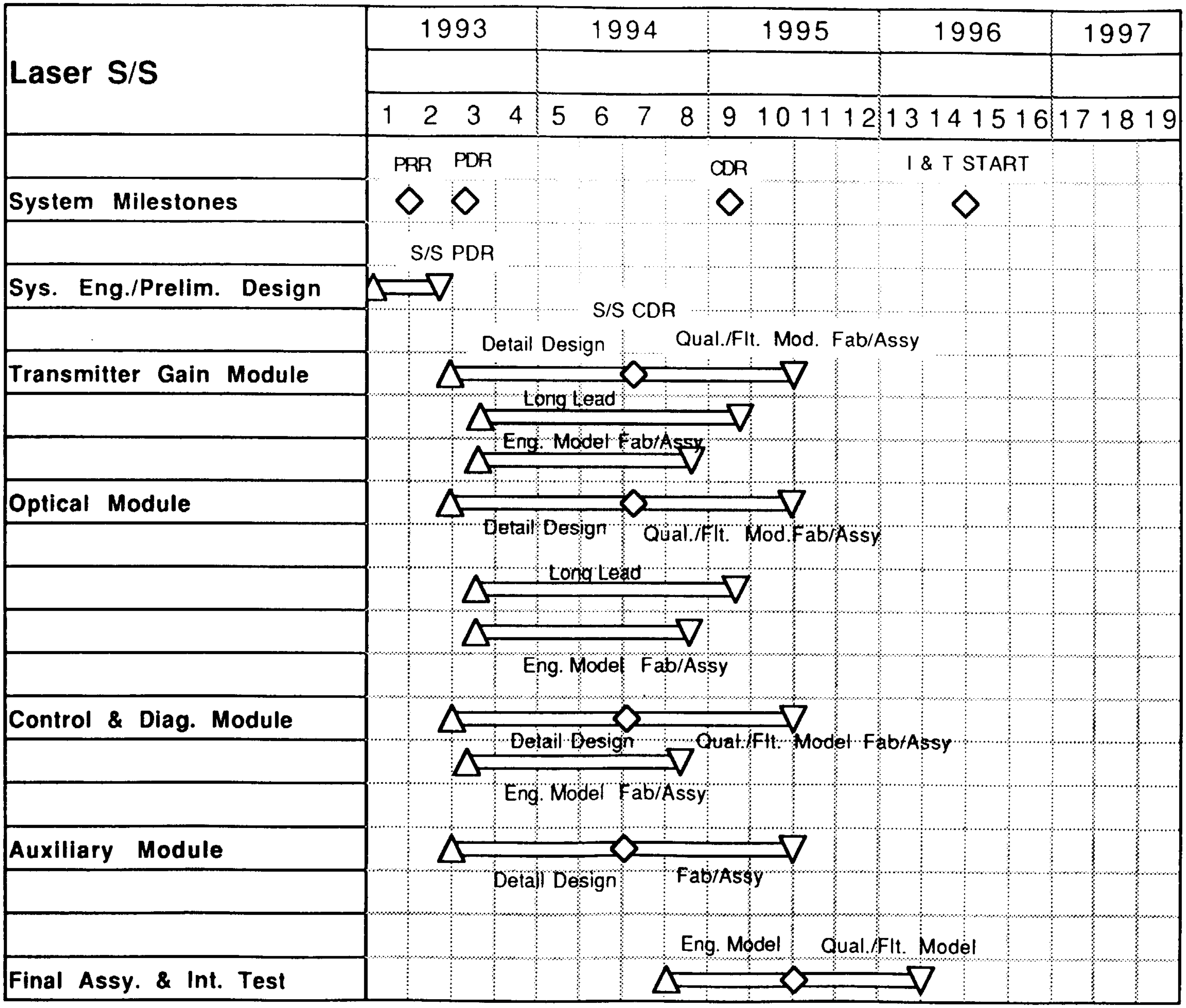


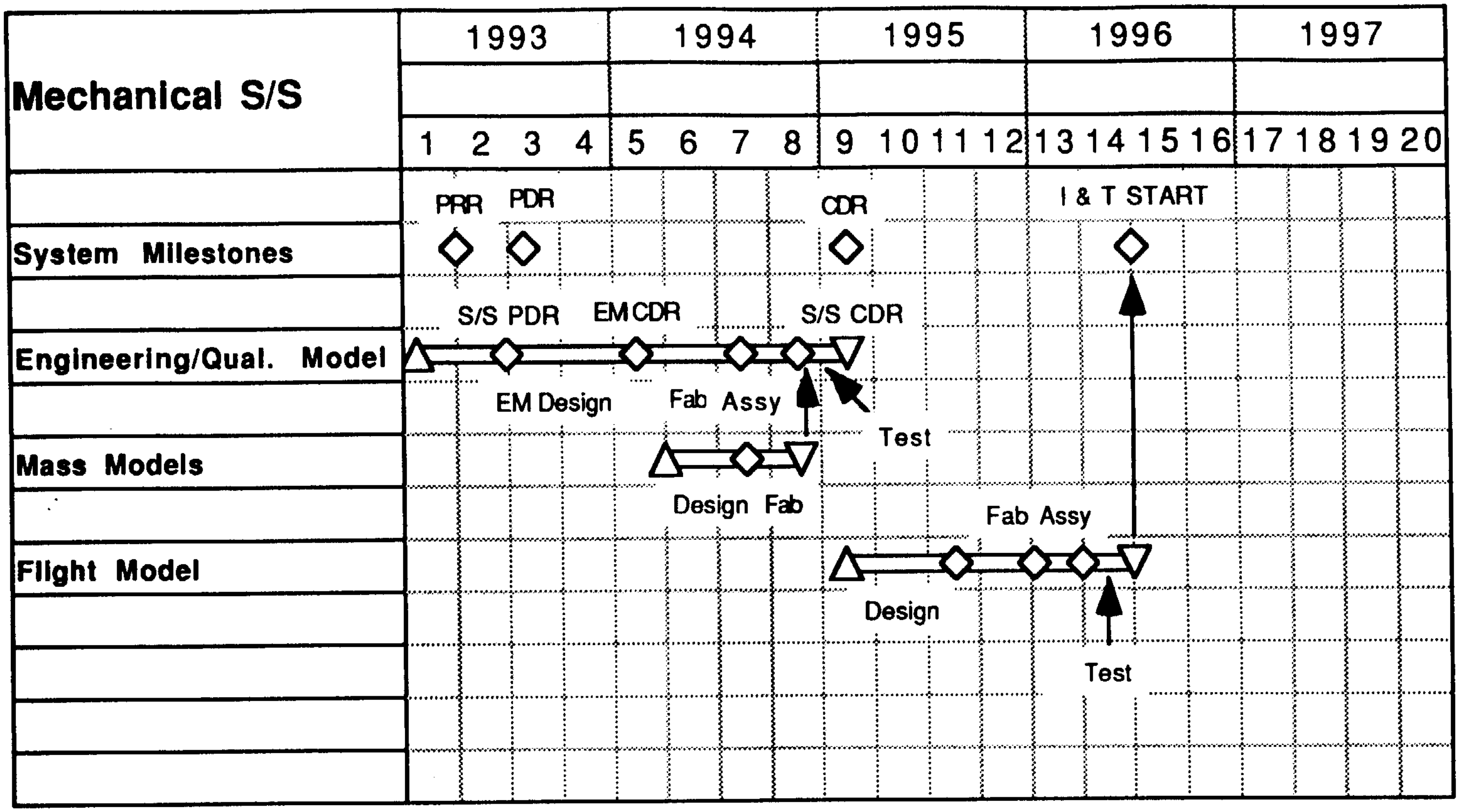
Sys. Engineering
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
PRR
PDR
CDR
I & T Start
Delivery
System Milestones
Mgmt. & Eng. Overview
Requirements
System
Subsys. Support
Design & Analysis
System
Subsys. Support
Sys. Verif. & Test
Plans
Support


Optics S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
System Milestones
PRR
PDR
CDR
I & T START
Sys. Eng./Prelim. Design
S/S PDR
S/S CDR
Telescope Assembly
Detail Design
Fab/Assy
Long Lead
Optics Assembly
Detail Design
Fab/Assy
Scan Mech. & Controls
Controls Design
Fab/Assy
Mechanism Design
Fab/Assy
Final Assy. & Int. Test
Int. & Test
Final Assy.

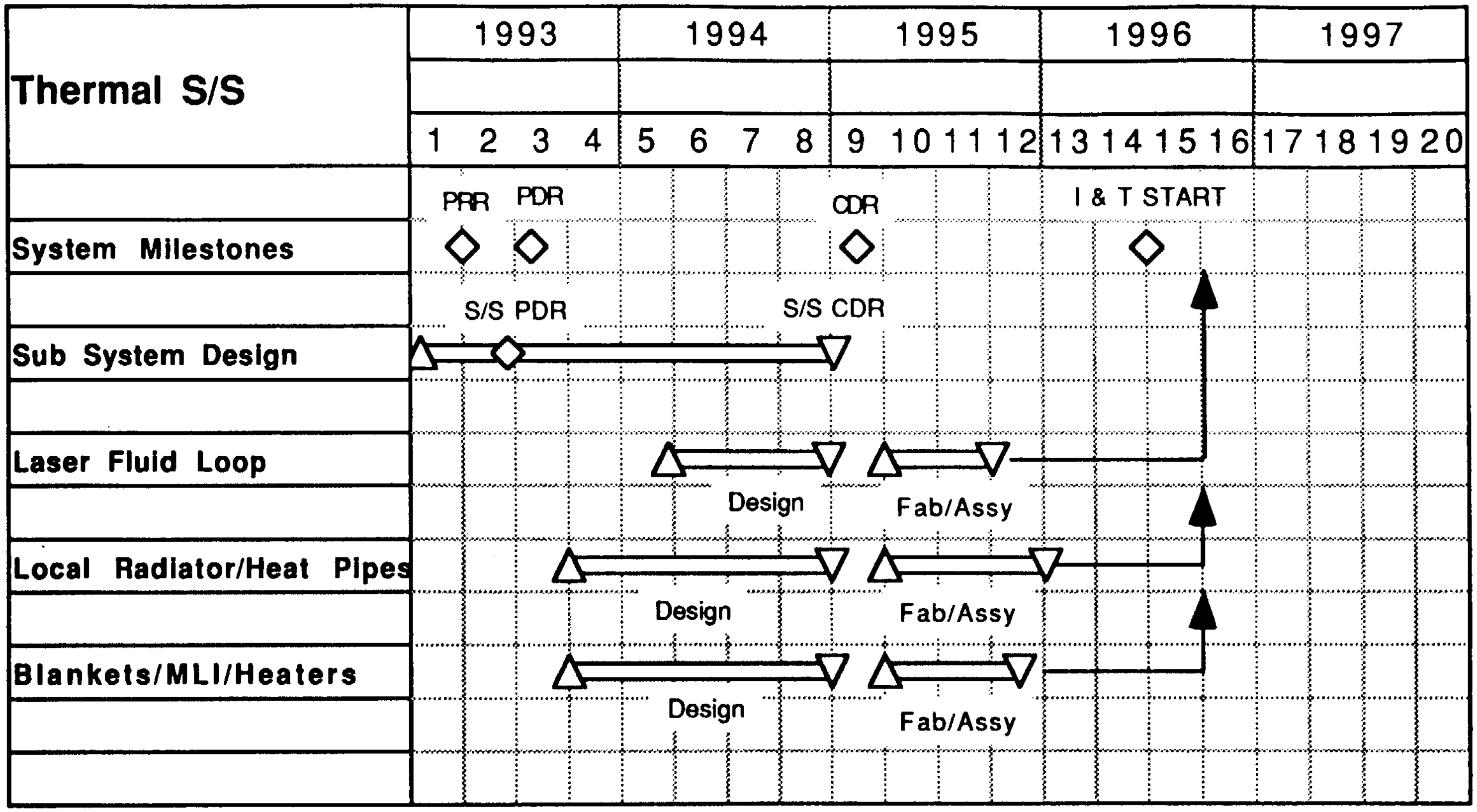


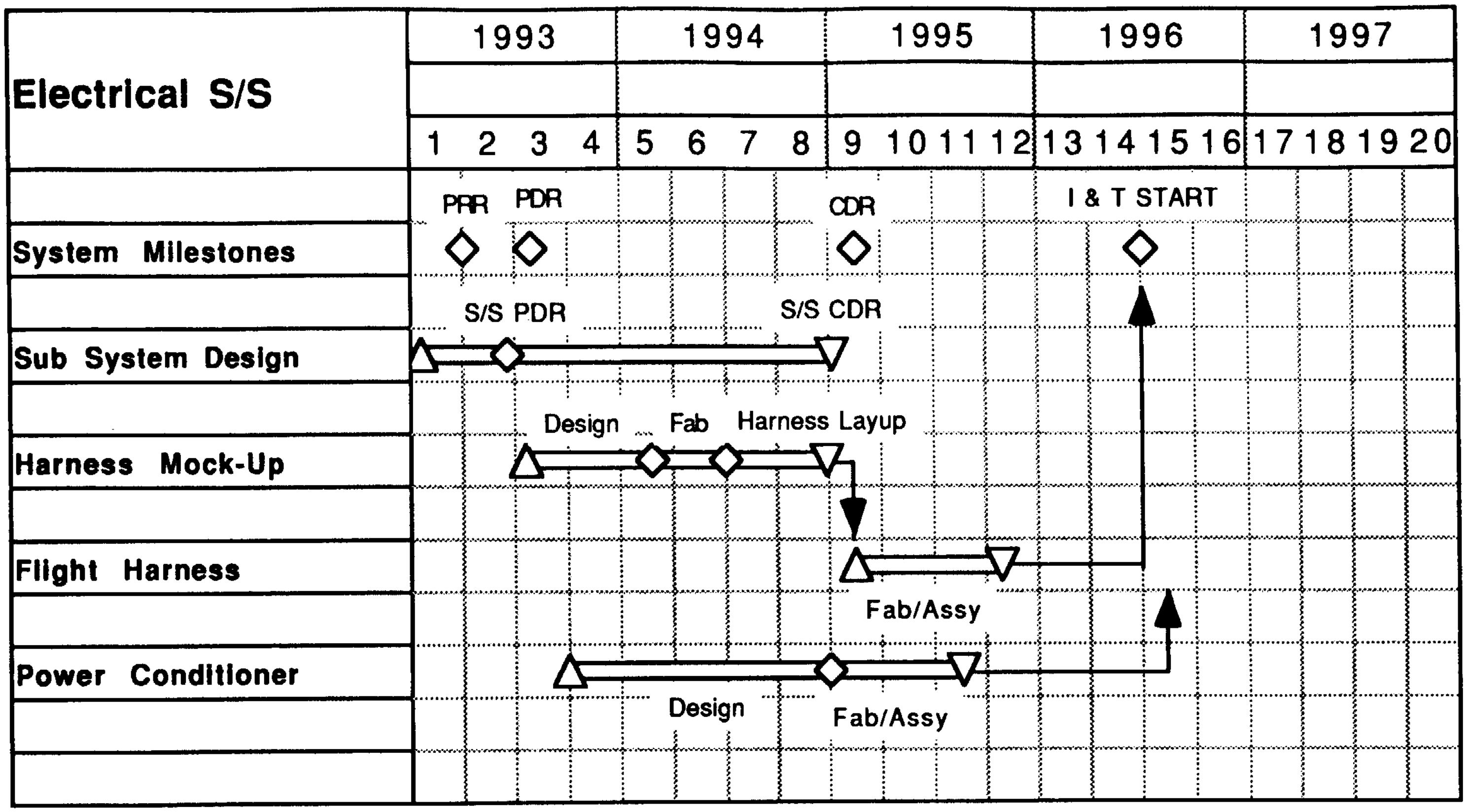
Receiver S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
System Milestones
PRR
PDR
CDR
I & T START
Sys. Eng./Prelim. Design
S/S PDR
S/S CDR
Detector/PreAmp
Detail Design
Fab/Assy
Cooler
Detail Design
Procure
IF Circuitry
Detail Design
Fab
Signal Processor
Detail Design
Fab
Power Supply
Detail Design
Fab
Controller
Detail Design
Fab
Cooler Breadboard (BB)
Procure
Test
Detector Preamp BB
Fab
Test
Electronics BB
Fab
Test
Final Assy. & Int. Test
Assembly Level
Subsys
Integration & Test


Laser S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
System Milestones
PRR
PDR
CDR
I & T START
Sys. Eng./Prelim. Design
S/S PDR
S/S CDR
Transmitter Gain Module
Detail Design
Qual./Flt. Mod. Fab/Assy
Long Lead
Eng. Model Fab/Assy
Optical Module
Detail Design
Qual./Flt. Mod.Fab/Assy
Long Lead
Eng. Model Fab/Assy
Control & Diag. Module
Detail Design
Qual./Flt. Model Fab/Assy
Eng. Model Fab/Assy
Auxiliary Module
Detail Design
Fab/Assy
Final Assy. & Int. Test
Eng. Model
Qual./Flt. Model

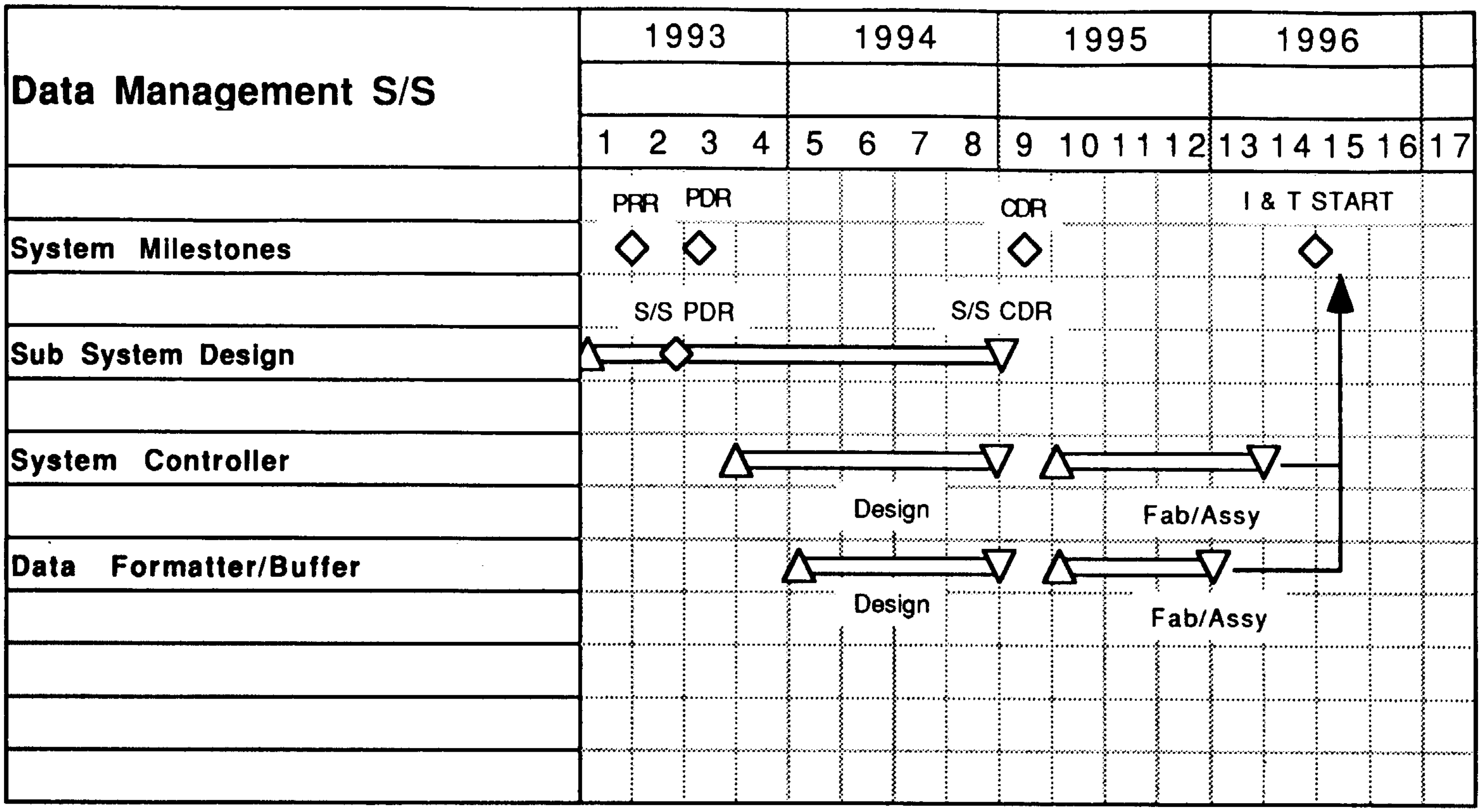


Mechanical S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PRR
PDR
CDR
I & T START
System Milestones
S/S PDR
EM CDR
S/S CDR
Engineering/Qual. Model
EM Design
Fab Assy
Test
Mass Models
Design Fab
Fab Assy
Flight Model
Design
Test

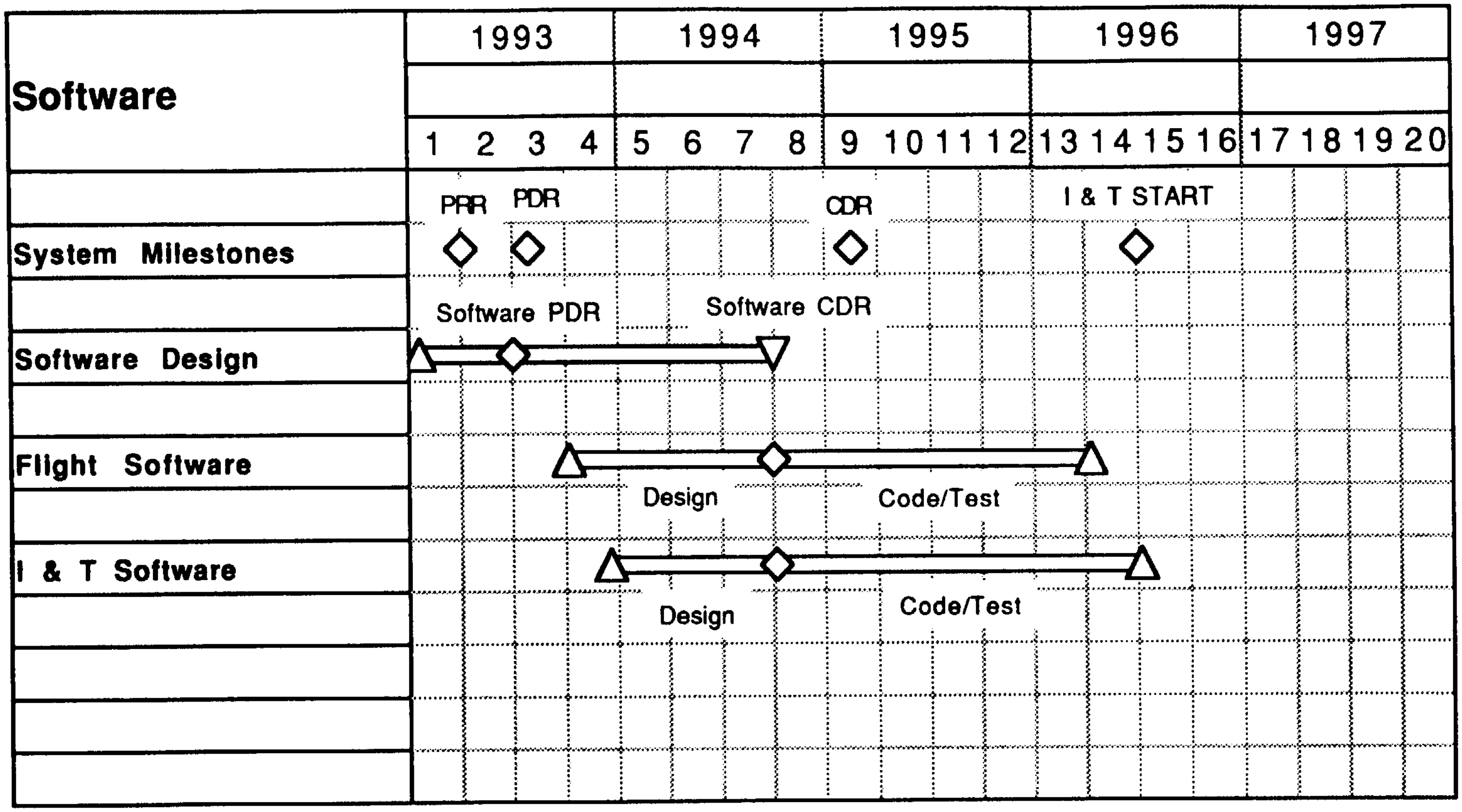

Thermal S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
System Milestones
PRR
PDR
CDR
I & T START
Sub System Design
S/S PDR
S/S CDR
Laser Fluid Loop
Design
Fab/Assy
Local Radiator/Heat Pipes
Design
Fab/Assy
Blankets/MLI/Heaters
Design
Fab/Assy

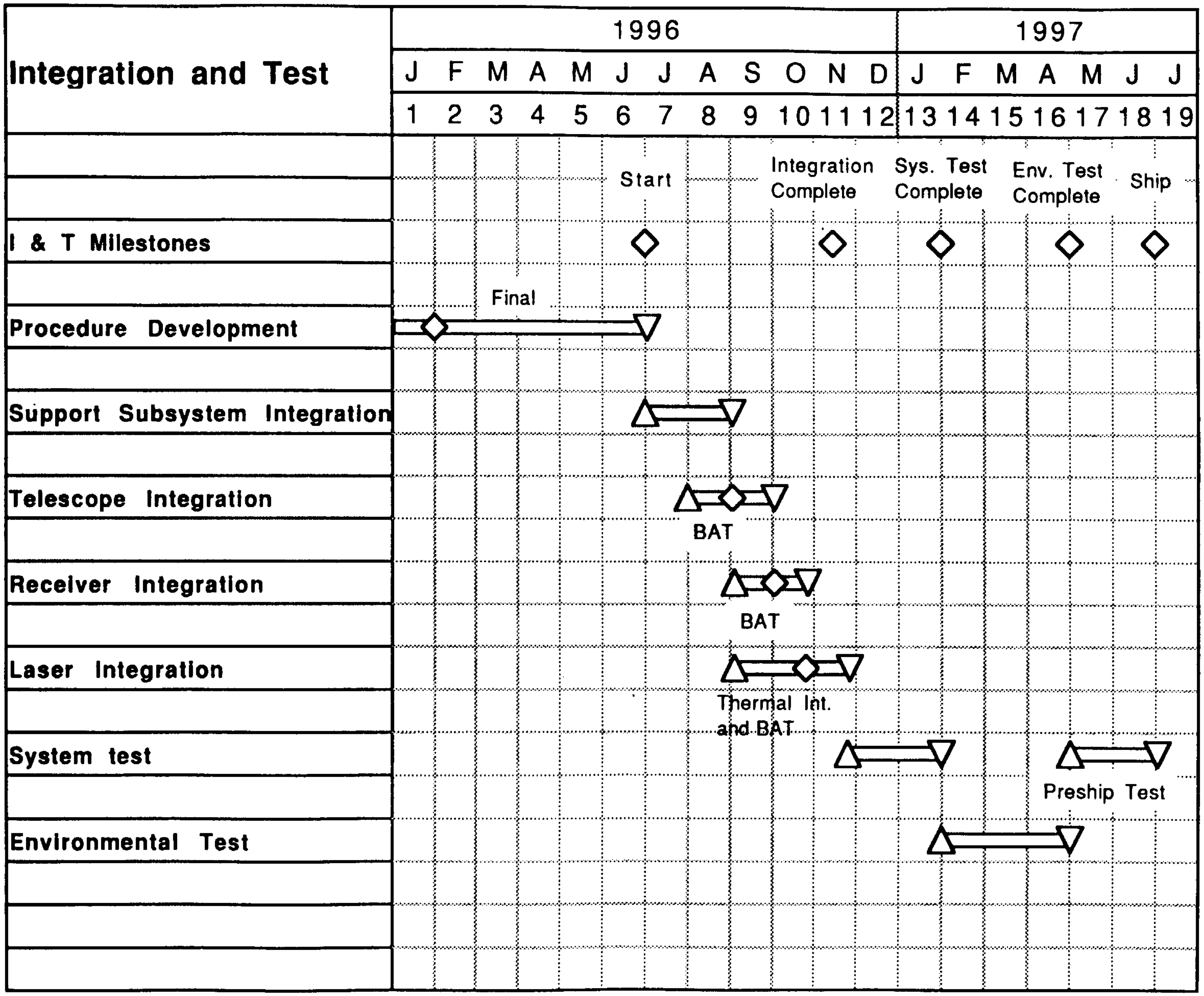


Electrical S/S
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
System Milestones
PRR
PDR
CDR
I & T START
Sub System Design
S/S PDR
S/S CDR
Harness Mock-Up
Design
Fab
Harness Layup
Flight Harness
Fab/Assy
Power Conditioner
Design
Fab/Assy



Data Management S/S
1993
1994
1995
1996
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
PRR
PDR
CDR
I & T START
System Milestones
S/S PDR
S/S CDR
Sub System Design
System Controller
Design
Fab/Assy
Data Formatter/Buffer
Design
Fab/Assy


Software
1993
1994
1995
1996
1997
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
System Milestones
PRR
PDR
CDR
I & T START
Software Design
Software PDR
Software CDR
Flight Software
Design
Code/Test
I & T Software
Design
Code/Test



Integration and Test
1996
1997
J F M A M J J A S O N D J F M A M J J
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
I & T Milestones
Start
Integration Complete
Sys. Test Complete
Env. Test Complete
Ship
Procedure Development
Final
Support Subsystem Integration
Telescope Integration
BAT
Receiver Integration
BAT
Laser Integration
Thermal Int. and BAT
System test
Preship Test
Environmental Test

ATTACHMENT

WORK BREAKDOWN STRUCTURE[WBS] AND WBS DICTIONARY

TABLE OF CONTENTS

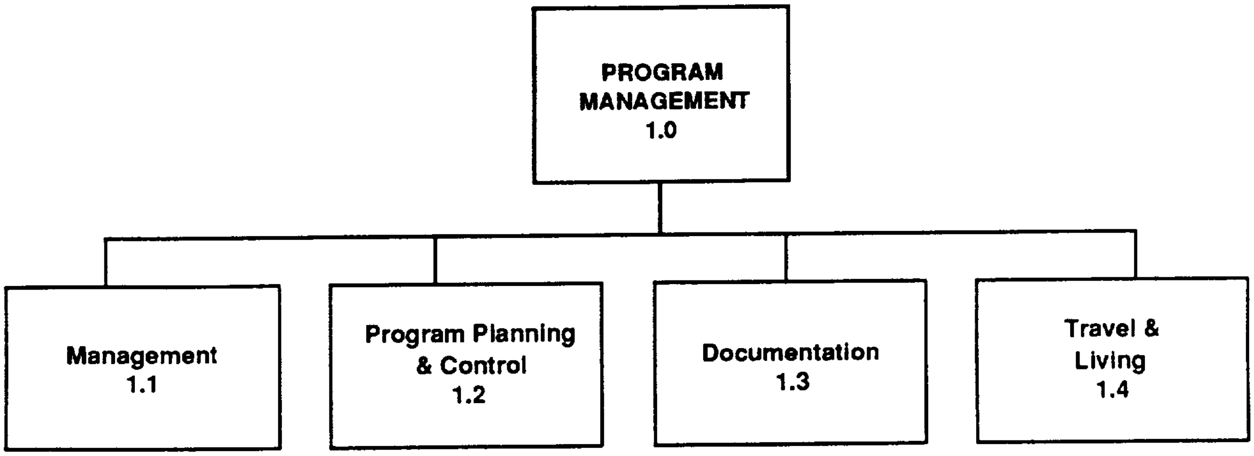
TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

INTRODUCTION

This document presents a WBS dictionary for the Laser Atmospheric Wind Sounder (LAWS).

The WBS dictionary provides work descriptions to the assembly level (level 6) for the three major LAWS subsystems: the transmitter, receiver, and optics subsystems. Work descriptions for the remaining hardware and functional elements are at the system (level 5) level.



1.0 PROGRAM MANAGEMENT

The Program Management element consists of the overall technical and business planning, organization, direction, integration, control and approval actions required to accomplish the program objectives.

1.1 Management

Provide overall program management direction and integration. Monitor overall program status and progress against program objectives, milestones, and schedules. Provide direction and integration of internal and customer directed change requests within the scope of the contract. Initiate, plan, direct and integrate program problem solutions and work arounds. Assure a continuing and timely response to customer inquiries, requests and changes.

Provide contract administration, subcontract administration, and financial management. Maintain program budgets. Provide financial monitoring of subcontract milestones.

1.2 Program Planning and Control

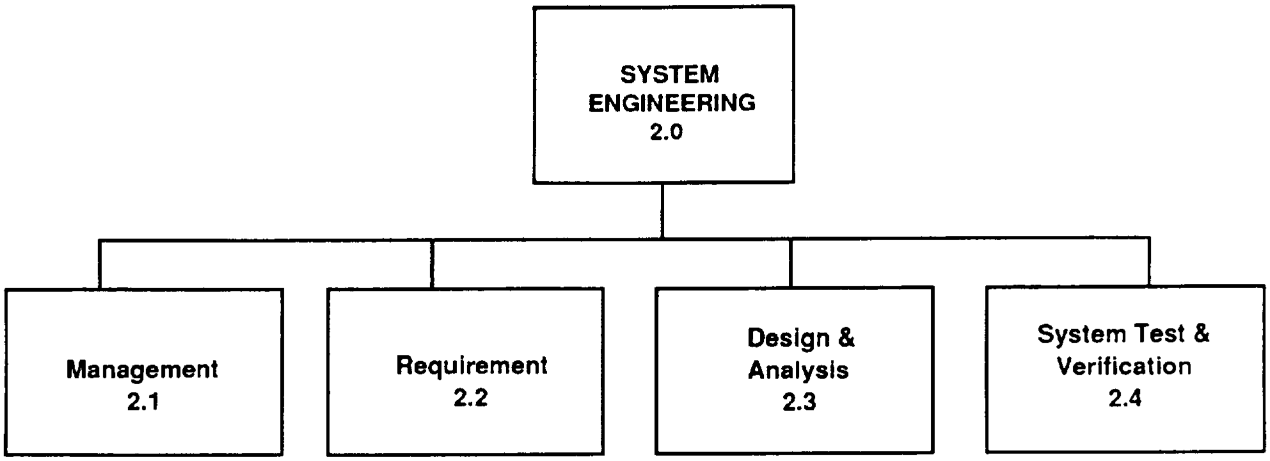
Provide a level of effort for implementing the performance measurement system. Provide program schedule development and management. Prepare and distribute PMS reports as required by contract.

1.3 Documentation

Develop, document, and implement configuration management plan. Establish, direct, control, analyze and implement data management system. Establish document library and management reporting system.

1.4 Travel & Living

Provide for all travel funds for customer reviews, vendor surveys, interface meetings, and all other program related travel.



2.0 SYSTEM ENGINEERING

The Systems Engineering element consists of developing and allocating requirements, integrating subsystems and technologies, performing system trades and analyses, defining and controlling interfaces, analyzing test results, participating in design reviews and assuring total system technical requirements are met.

2.1 Management

Includes systems engineering manager and secretary, travel and living expenses for systems engineering.

2.2 Requirements

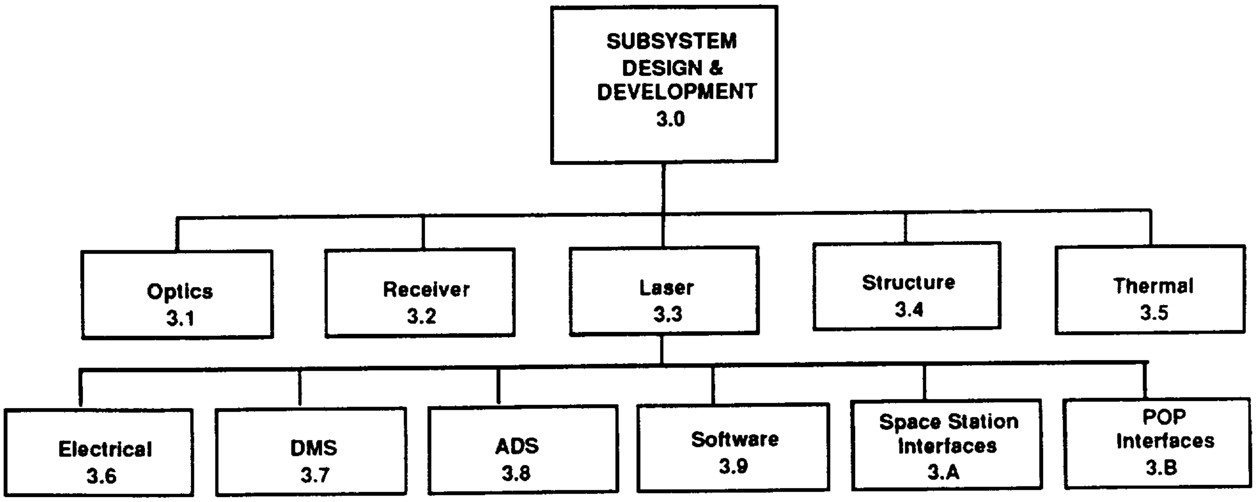
Define and control system requirements and interfaces. Obtain a preliminary mission operations concept. Identify system driven requirements for subsystems. Prepare and maintain the LAWS specification and specification tree. Prepare requirements traceability matrix. Identify external and internal interface requirements.

2.3 Design & Analysis

Perform design tradeoffs and verification analyses. Develop and allocate error budgets for pointing and alignment. Perform trade studies for LAWS power and weight, and measurement accuracy.

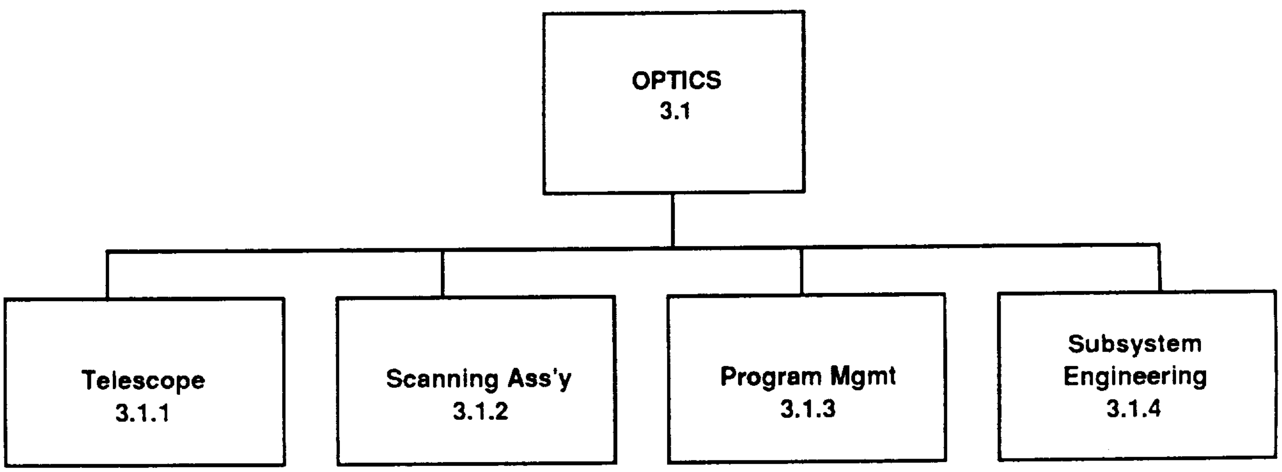
2.4 System Test & Verification

Assure that the performance of the hardware subsystems and the flight software are fully verified. Develop requirements verification matrix. Assure that the subsystem and component environmental testing is properly planned and conducted. Prepare the end-to-end compatibility test plan. Evaluate the results of all system level verifications.



3.0 SUBSYSTEM DESIGN AND DEVELOPMENT

Subsystem design and development involves developing the hardware subsystems for the LAWS instrument, the flight software, and the interface engineering tasks required for the Japanese Polar Orbiting Platform (JPOP) or the Space Station Freedom, as required. It is the nonrecurring part of the subsystem activity.

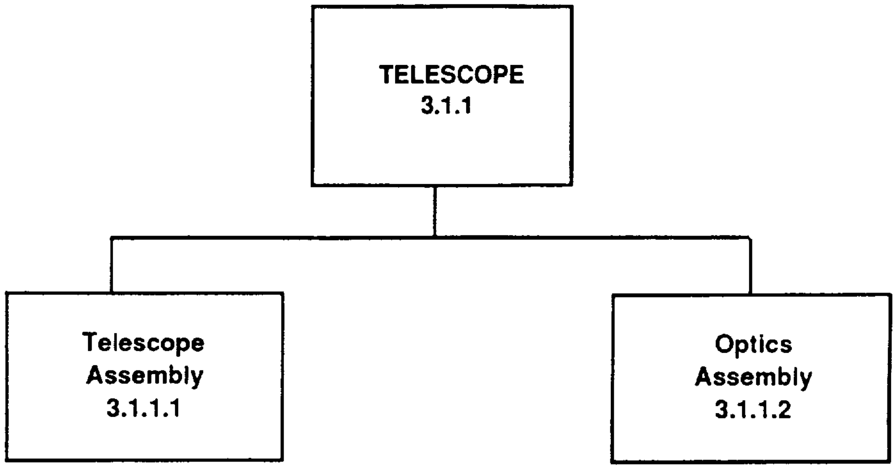


3.1 Optics

The Optics Subsystem consists of a large-aperture beam expander/telescope, relay optics assembly, scanner mechanism, and scan controls.

The tasks have been defined in this document to the program level six, with further details for some elements to level seven when needed for proper definition.

The task includes all of the engineering, analysis, design effort, and developmental materials, hardware, test equipment, software and services to manage, design and develop the LAWS Optics Subsystem. The costs associated with these tasks constitute the non-recurring part of the subcontract.



3.1.1 *Telescope*

Perform engineering, design, development, design/development verification and qualification tests, and prepare specification of the Telescope. Perform design/development testing as required to finalize the design. Provide verification test concepts.

The Telescope includes the large aperture beam expander/telescope assembly and associated relay optics that expand the outgoing high energy laser beam and collect and deliver to the receiver the radiation backscattered from the atmosphere.

The Telescope interfaces mechanically and optically with the pointing subsystem, laser, receiver and the vehicle payload mounting plate, electrically with the Power, and the Structure and Thermal support subsystems.

3.1.1.1 *Telescope Assembly*

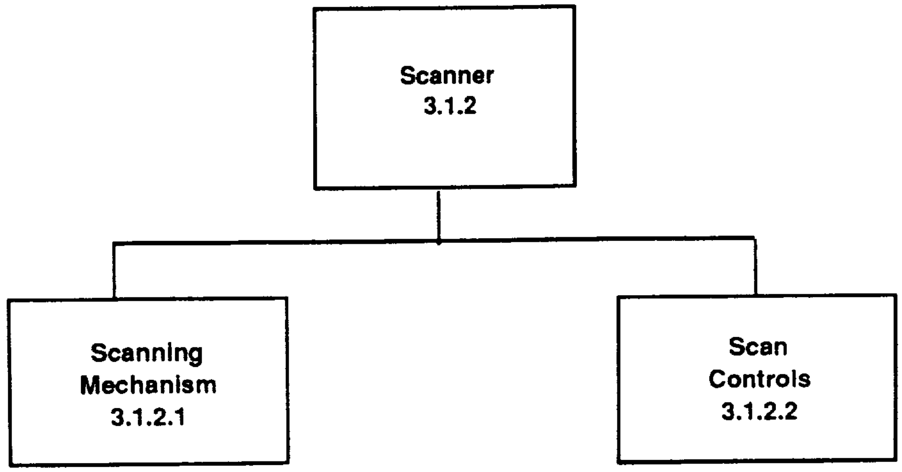
Provide telescope design layouts, structural and thermal analyses, alignment sensing and control design, make/buy plans for large optic blanks, mirror cells, metering and support structures and light baffles and thermal shrouds. Provide mechanical interface definition and designs.

Perform laboratory developmental testing as required for selected components of the telescope; in particular, the alignment sensing and control components.

3.1.1.2 *Optics Assembly*

Provide optical relay design layouts, tolerance and sensitivity data, structural and thermal analyses, transmit/receive switch design, lag angle compensator design, laser/receiver alignment monitor design, structural/thermal design, and make/buy plans for each of these components. Provide mechanical interface definition and designs.

Perform laboratory developmental testing as required for selected components of the optics assembly.



3.1.2 *Scanner*

Perform engineering, design, development, design/development verification and qualification tests, and prepare specification of the Pointing Subsystem. Provide verification test concepts.

The Scanner includes the pointing and scanning controls for directing the outgoing beam, compensating for the lag angle and spacecraft induced image motions, and implementing the transmit/receive functions of the system.

The Scanner interfaces mechanically and optically with the Telescope, electrically with the Power, DMS, ADS, and Software support subsystems.

3.1.2.1 *Scanner Mechanism*

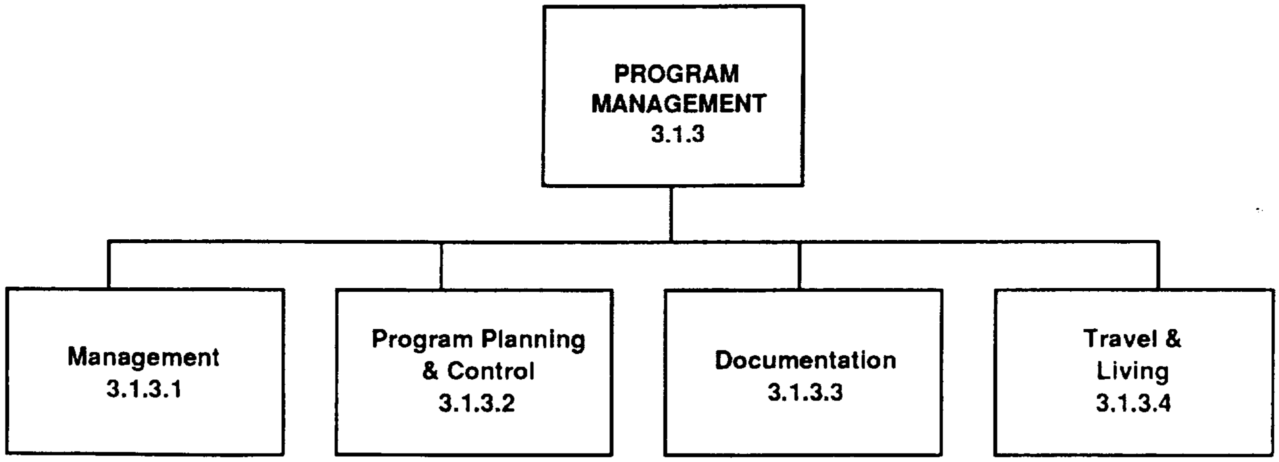
Prepare design and procurement specification for scan mechanism bearings, drive, encoder, and tachometer. Provide source selection for these components. Prepare make/buy plan for support ring assembly. Provide design support and monitoring as required. Prepare mechanical/electrical interface drawings.

Perform design/development testing as required to finalize design.

3.1.2.2 *Scan Controls*

Provide the functional and design specifications for the scan control electronics boxes. Perform design/development testing as required to finalize the design. Perform a make/buy analysis and plan. Provide source selection for items to be procured.

The scan controls consist of the electronics necessary to control the functions of the Optics, and include the scan mechanism drive and control electronics, the transmit/receive switch controller and synchronizer, the lag angle compensation controller, and sensor interface conditioning electronics.



3.1.3 *Program Management*

Provide all resources required to manage and control the optical subsystem (technical and cost) program effort. Management customer program reviews and all contractual data requirements will be performed under this task.

3.1.3.1 *Performance Management*

Perform planning, management and control of the technical performance of the LAWS Optical Subsystem program. Organization, preparation and execution of all formal and informal prime contractor, NASA and internal management reviews.

3.1.3.2 *Planning/Controls*

Implementation and cost schedule management, using our existing performance management system. Design and maintain the cost and schedule baseline. Analyze and report cost and schedule variances. Weekly status and monthly update of all program schedules.

3.1.3.3 *Documentation*

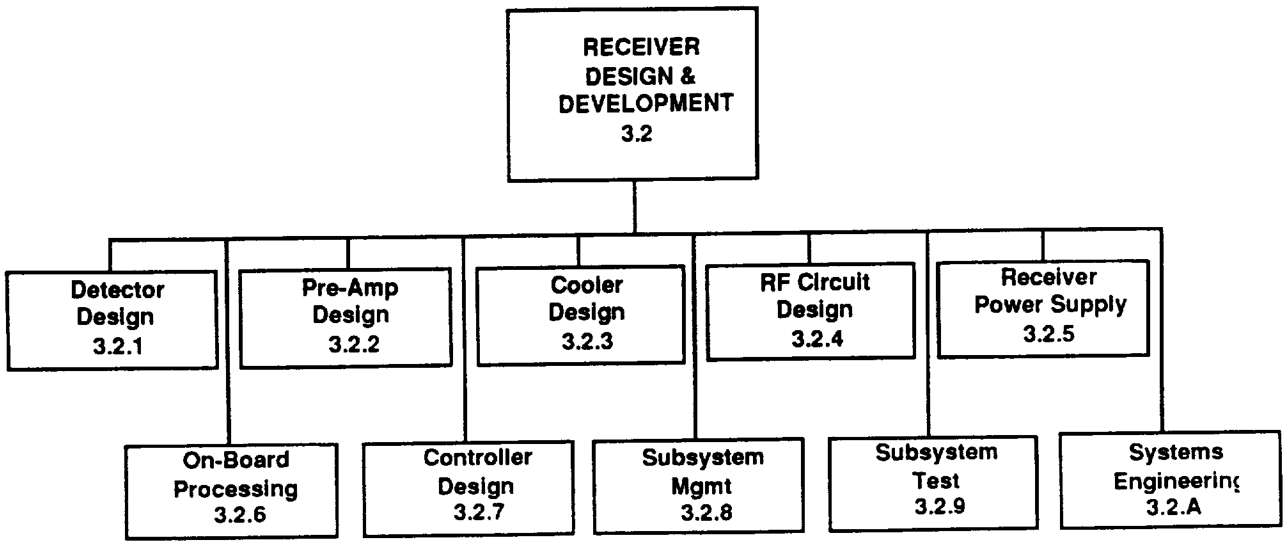
Performs technical-documentation tasks required to process (edit, type, illustrate) all material for prime contractor's contractually-required DRs. Prepare material for all contractual reviews.

3.1.3.4 *Travel*

Cost account for all necessary travel funds for customer (Prime Contractor and NASA) reviews; vendor surveys; interface meetings; and all other program related travel. The labor associated with the travel is located in the pertinent activity task.

3.1.4 *Subsystem Engineering*

Perform all activities necessary to assure compliance with the LAWS and Optical Subsystem contractual and performance specifications, to insure operational effectiveness and flexibility, and to support the integrated LAWS system design, and to establish technical requirements necessary to achieve these objectives. Perform and document analyses as required to define interfaces between the Optical Subsystem and other LAWS subsystem hardware and software.



3.2 Receiver Design and Development

Receiver design and development involves the design and development of the entire receiver subsystem including the detector, preamplifiers, cooler, RF circuits, power supply, receiver controller/monitor, subsystem test, systems engineering and subsystem management.

3.2.1 *Detector Assembly Design and Development*

This task includes detailed performance analysis and interface documents for the entire detector assembly including the HgCdTe detector elements and detector packaging. Verify all performance specifications, including detector bandwidth, required LO power, operating temperature and quantum efficiency. Evaluate and document all reliability, survivability and safety issues associated with the detector assembly.

The detector assembly development will consist of an engineering unit for verification testing only.

3.2.2 *Detector Pre-amplifier Design and Development*

This task includes the design and development of the detector pre-amp. Verify all performance specifications including pre-amp gain, noise figure, and required power. Evaluate and document all reliability, survivability and safety issues associated with the detector assembly.

The pre-amp development will consist of an engineering unit for verification testing.

3.2.3 *Cooler Design and Development*

Develop detailed cooler design including all interface and performance documents. Verify and document cooler capabilities, heat load, vibration (microphonics), heat rejection, interface and power requirement specifications. Evaluate and document all reliability, survivability and safety issues associated with the coolers.

A prototype unit will be required for verification testing of vibration and thermal gradient performance.

3.2.4 *RF Circuit Design and Development*

This task involves the detailed RF circuit design including all assembly interfaces, performance specifications, requirements documents and test procedures. These specs include detailed frequency synthesizer accuracy and required power levels. Evaluate and document all reliability, survivability and safety issues associated with the RF circuitry.

RF circuit development will consist of an engineering model and verification testing.

3.2.5 *Receiver Power Supply Design and Development*

The receiver power supply design includes the development of specific power requirements for the detector pre-amp, cooler, RF circuits, data processing, and detector bias voltage. Evaluate and document all reliability, survivability and safety issues associated with the receiver power supply.

The receiver power supply development will consist of an engineering unit for verification testing.

3.2.6 *On-board Processing Design and Development*

This task involves the detailed processor design including the specific algorithms to be implemented, the electronics design and the thermal and power interface requirements. Evaluate and document all reliability, survivability and safety issues associated with the processing.

The on-board processing development will consist of an engineering model and verification testing.

3.2.7 *Receiver Controller/Monitor Design and Development*

This includes development of detailed specifications for the receiver controller software. This controller/monitor will provide two-way data links with the detector, pre-amp, cooler, RF electronics and signal processing electronics. Evaluate and document all reliability, survivability and safety issues associated with the controller.

This controller/monitor will consist of a single board to be input to the system controller.

3.2.8 *Management*

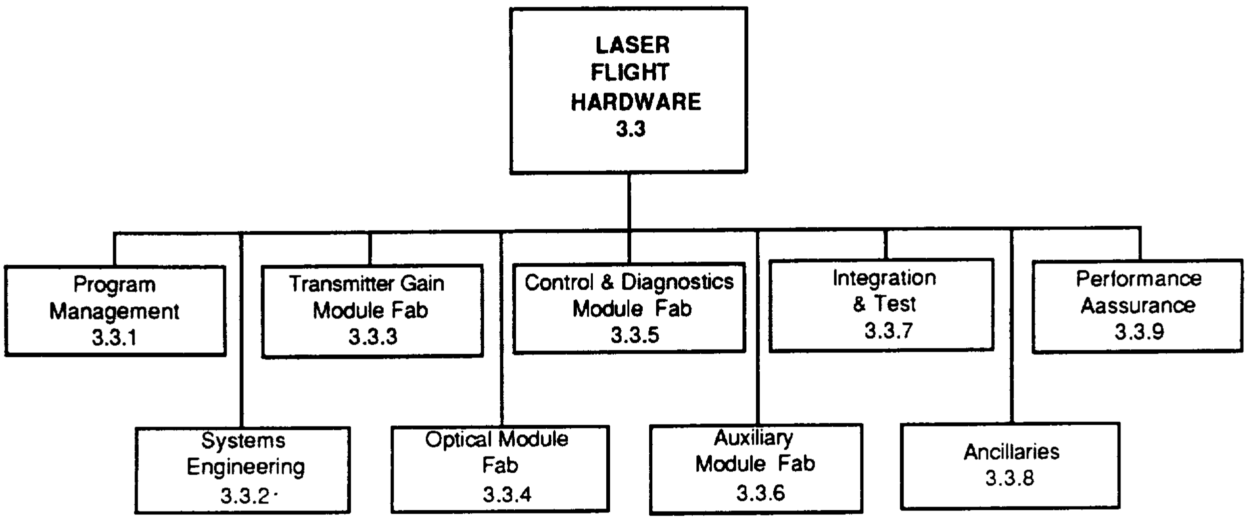
This task includes technical direction, customer support, subcontract management, reviews, and documentation and reporting.

3.2.9 *Subsystem Test*

This task involves subsystem level testing of the breadboard, brassboard and/or engineering assemblies, where appropriate.

3.2.A *Systems Engineering*

This task includes the overall subsystem performance analysis and review of all subsystem level requirements and specifications. Also included is any required test planning and interface with the other subsystems. Evaluate and document all subsystem level reliability, survivability and safety issues.



3.3 Laser Subsystem Design and Development

The Laser Subsystem has as its primary function the generation of two infrared beams: 1) the high power transmitter and 2) the local oscillator beams, respectively. The transmitter beam is provided to the Optics Subsystem, and the local oscillator beam is provided to the Receiver Subsystem. It derives its prime power from the platform via the sensor power distribution panel, and firing synchronization and power up commands from the sensor control computer. It distributes waste heat to the sensor cold plate and health, status and diagnostic information to the sensor control computer and signal processor, respectively. Mechanical interfacing to the sensor is implemented via two Modules: the Transmitter Gain and Optical Modules assemblies respectively.

This task involves the design and development of the Engineering, Qualification and Flight units, respectively; and the fabrication and testing of the Engineering and Qualification units.

3.3.1 *Program Management*

This task includes technical direction, program planning and control, all documentation (reviews, manuals, data management and drawing package) and subcontract administration.

3.3.2 *System Engineering*

Under this task, subsystem requirements and specifications are set. Major assembly modeling tasks are undertaken, where required, during the period leading up to CDR. Test plans are generated for all subsystem and sensor tests and test results are evaluated. Specifications for subsystem interfaces with the instrument are generated. Subsystem reliability and risk issues are evaluated and documented.

3.3.3 *Transmitter Gain Module Design and Development*

The laser transmitter gain module constitutes those components that effect excitation of the laser medium, and condition it for rep-rated operation. Its major sub-elements are the discharge region, pulsed-power (high voltage) supply, flow loop and fan, heat exchanger, catalytic converter and shell. This task accomplishes the detailed design of these components. Interface documents for the various components and the integrated assembly will be generated. Due consideration is given to minimizing EMI and vibration leakage. Design Verification Tests will be performed as required during the period leading up to CDR.

3.3.4 *Optical Module Design and Development*

The optical module consists of all optical components and the athermal structure for their support. The support structure is attached directly to the sensor platform via vibration isolation connectors. This task involves the design and development of the structure and interface points, and optical components and sensors for laser beam control and diagnosis viz. the resonator optics, injection/local oscillator lasers, interferometer optics, alignment system optics and subsystem photodetectors. The interface with the control and diagnostics module is also part of this task. Design Verification Tests are conducted as required in the period leading up to CDR.

3.3.5 *Control and Diagnostics Module Design and Development*

The control and diagnostics module accepts commands from the sensor host computer and feedback from the sensors in the optical module and in turn controls the operation of the laser and provides information to the host computer and signal processor. The laser control functions includes the laser frequency servo-loops and alignment system logic circuitry. Health and status and beam diagnostic information is provided the host computer and signal processor. This task accomplishes the design and development of the software and control voltage circuitry required.

3.3.6 *Auxiliary Module Design and Development*

This task accomplishes the design and development of support equipment for ground-based operation of the flight unit during subsystem checkout and acceptance tests, sensor integration and preflight tests, storage and on-orbit deployment.

3.3.7 *Engineering and Qualification Model Fabrication*

Under this task the Engineering and Qualification unit assemblies are fabricated to conform with the designs generated in Task elements 3.3.3 through 3.3.6.

3.3.8 *Integration and Test*

Test facilities are built to facilitate conduct of the subsystem tests defined in Task element 3.3.2.0. Tests are performed on individual components and assemblies. The Engineering and Qualification assemblies are integrated and the completed subsystems undergo functional testing. The Qualification unit is subjected to extensive environmental testing. Test reports are prepared.

3.3.9 *Performance Assurance*

Subsystem product assurance guidelines are developed and applied to the fabrication of the Qualification unit. Subsystem safety and survivability assessments are conducted and documented.

3.4 Structure

Design and develop the mechanical support structure for the LAWS flight hardware. Design the instrument support structure and any supporting structure required for interfacing to the platform.

Provide subsystem project engineering support and manufacturing level of effort conducted at the subsystem level. Develop a mechanical test model (MTM) and Mass Models of the instrument subsystems to provide verification of the finite element analysis of the instrument support structure, demonstrate alignment procedures and provide alignment data. The MTM may also be used to provide qualification data for the flight hardware. Perform harness mockup activity which will use the model of the primary structure to lay-up harness models from which harness boards necessary for the fabrication of the flight harnesses will be constructed.

3.5 Thermal

Design and develop the thermal subsystem of the LAWS hardware. Perform all analyses and develop hardware required to keep the instrument within the acceptable temperature limits during normal mission operations.

Design and develop the laser fluid loop for removing the heat from the laser to the platform cold plate.

Provide subsystem project engineering support and the manufacturing level of effort conducted at the subsystem level. Design and develop radiators to dissipate the heat produced by the LAWS hardware. Identify, procure and test heaters, temperature sensors and thermostats.

Design blankets, blanket supports, radiators, and thermal coatings, as required. Define thermal tests to verify the accuracy of the thermal analysis and modeling of the LAWS hardware.

3.6 Electrical

Design and develop the electrical subsystem of the LAWS hardware. Provide subsystem project engineering support and the manufacturing level of effort conducted at the subsystem level. Design and develop the harnesses. Note: fabrication of model hardware and lay-up of the harness mock-up is conducted in task 3.4.

Design and develop the power conditioner for the LAWS hardware. The power conditioner accepts spacecraft power and converts it to the voltages required by the instrument subsystems. Note, the laser contains its own power conditioners.

3.7 Data Management System (DMS)

Design and develop the DMS for LAWS. Provide subsystem project engineering support and the manufacturing level of effort conducted at the subsystem level.

Design and develop the lidar system controller. The system controller is the instrument interface with the spacecraft. It receives clock signals and commands from the spacecraft, as necessary, and handles the protocols and schedules for transferring data from the instrument to the spacecraft data bus for subsequent transmission to the ground.

Design and develop the data formatter and buffer. The data formatter/buffer serves as the interface between the receiver RF electronics and the system controller.

3.8 Attitude Determination System (ADS)

Design and develop the ADS for LAWS. The ADS provides the attitude information which enables the LAWS instrument to determine its position with respect to the spacecraft and the Earth. This information is necessary for removal of the spacecraft and Earth induced Doppler shifts from the LAWS data. It is anticipated that an ADS will only be required for Space Station operation of the LAWS instrument.

Analyze and define the ADS hardware. Develop the attitude determination algorithms. Specify and procure the ADS.

Specify and procure the momentum conpensation assembly.

3.9 Software

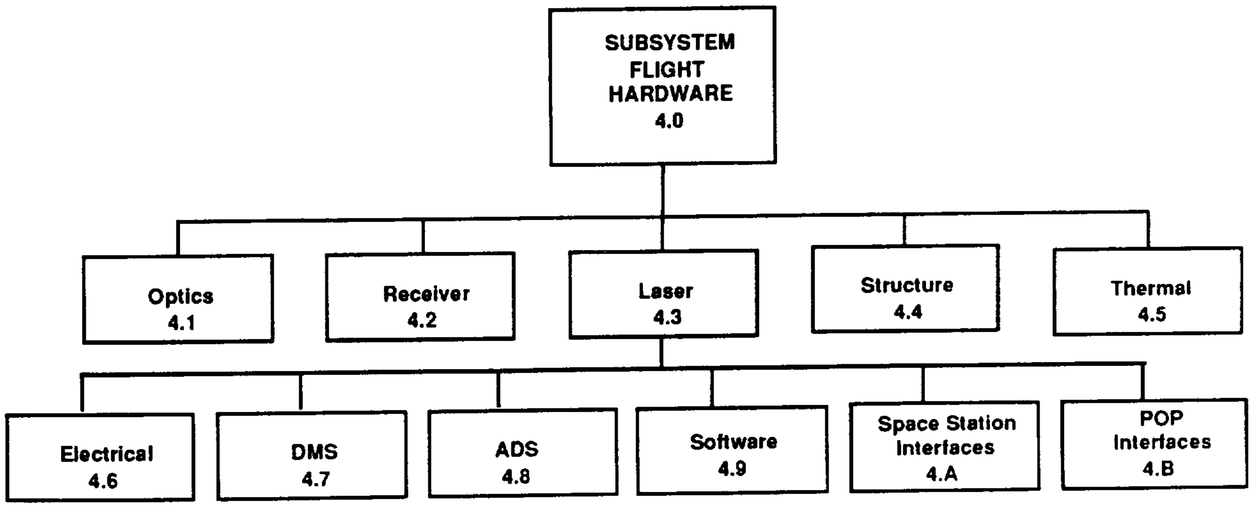
Define the software, including planning, requirements definition, specification and test plan preparation. Develop (coding) and validate the flight software. Design and develop a software test facility for the validation of the flight software.

3.A Space Station Interface

Design and development of the interface of LAWS with the Space Station Freedom. Define the mechanical, electrical, data, and thermal interfaces. Provide mechanical, electrical, data and thermal subsystem engineering support.

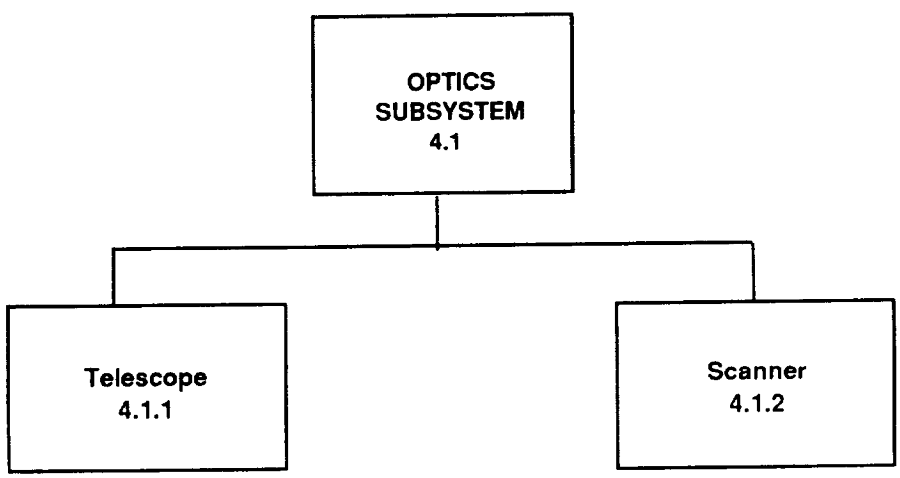
3.B Japanese Polar Platform (JPOP) Interface

Design and develop the interface of LAWS with the Japanese Polar Platform. Define the mechanical, electrical, data, and thermal interfaces. Provide mechanical, electrical, data and thermal subsystem engineering support.



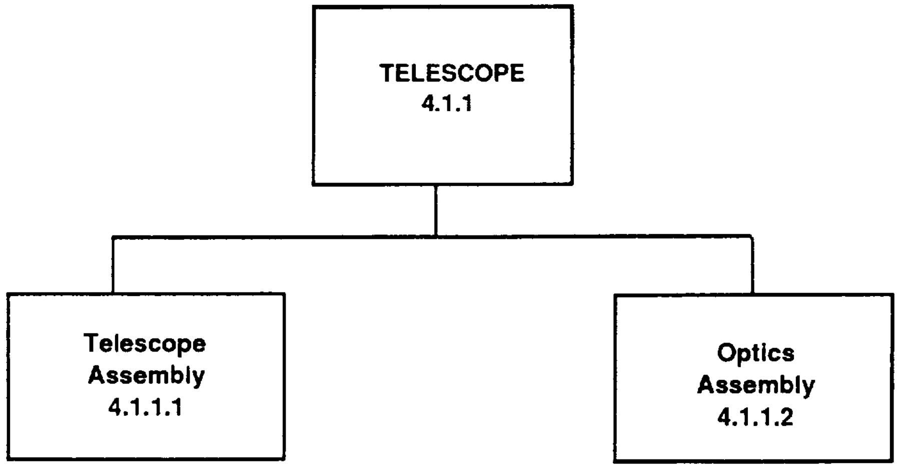
4.0 SUBSYSTEM FLIGHT HARDWARE

Subsystem flight hardware includes fabrication, integration and test of the subsystem for the LAWS instrument, the flight software, and interface tasks required for accommodation onto a platform. It is the recurring part of the subsystem activity.



4.1 Optics

This task includes all of the effort, material, tooling, hardware, software and services to manage, procure, fabricate, assemble, verify, and ship the LAWS flight unit and to support the LAWS assembly, integration and verification, launch, orbital verification and mission operations planning. The costs associated with these tasks constitute the recurring part of the subcontract.



4.1.1 *Telescope*

Perform and provide all of the engineering, manufacturing, materials, tooling, hardware and software, and services required to manage, procure, fabricate, assemble, verify, integrate, and ship the Telescope. Conduct Telescope acceptance testing. Provide verification support.

The telescope includes the large aperture beam expander/telescope assembly and associated relay optics that expand the outgoing high energy laser sounding beam and collect and deliver to the receiver the radiation backscattered from the atmosphere.

The telescope interfaces mechanically and optically with the pointing subsystem, laser, receiver and the vehicle payload mounting plate, electrically with the Power, and Structure and Thermal support subsystems.

4.1.1.1 *Telescope Assembly*

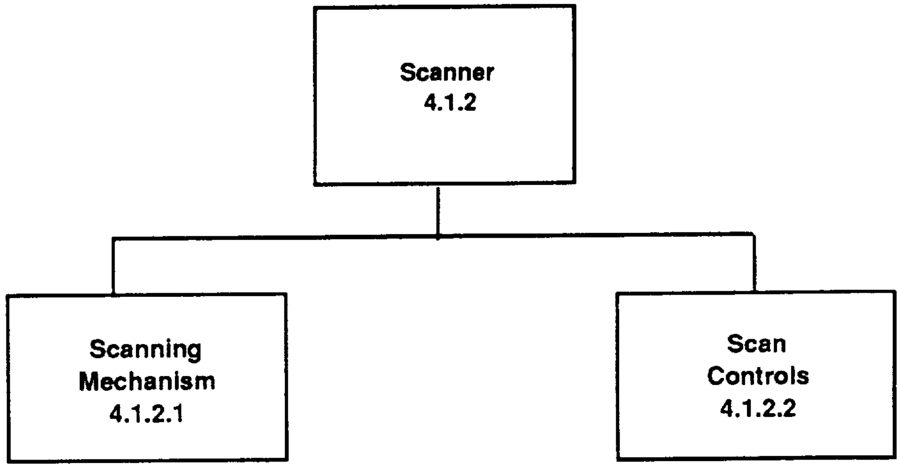
Provide all telescope material, tooling, alignment sensing and control components, large optics, mirror cells, metering, support structures and light baffles and thermal shrouds. Provide manufacturing and assembly plans and procedures, and manufacturing and engineering effort to execute these plans.

Perform component and subassembly qualification testing as required for selected components of the telescope; in particular, for the alignm ent sensing and control components.

4.1.1.2 *Optics Assembly*

Provide materials, tooling, components, manufacturing and assembly plans and procedures for the optical relay, structural and thermal systems, transmit/receive switch assembly (if necessary), lag angle compensator assembly, and laser/receiver alignment monitor system. Provide manufacturing and assembly plans and procedures, and manufacturing and engineering effort to execute these plans.

Perform component qualification testing as required for selected components of the optics assembly.



4.1.2 *Scanner*

Perform and provide all of the engineering, manufacturing, materials, tooling, hardware and software, and services required to manage, procure, fabricate, assemble, verify, integrate, and ship the scanner Subsystem. Conduct scanner subsystem acceptance testing. Provide verification support.

The Scanner includes the pointing and scanning controls for directing the outgoing beam, compensating for the lag angle and spacecraft/induced image motions, and implementing the transmit /receive functions of the system.

The Scanner interfaces mechanically and optically with the Telescope, electrically with the Power, DMS, ADS, and Software support subsystems.

4.1.2.1 *Scanner Mechanism*

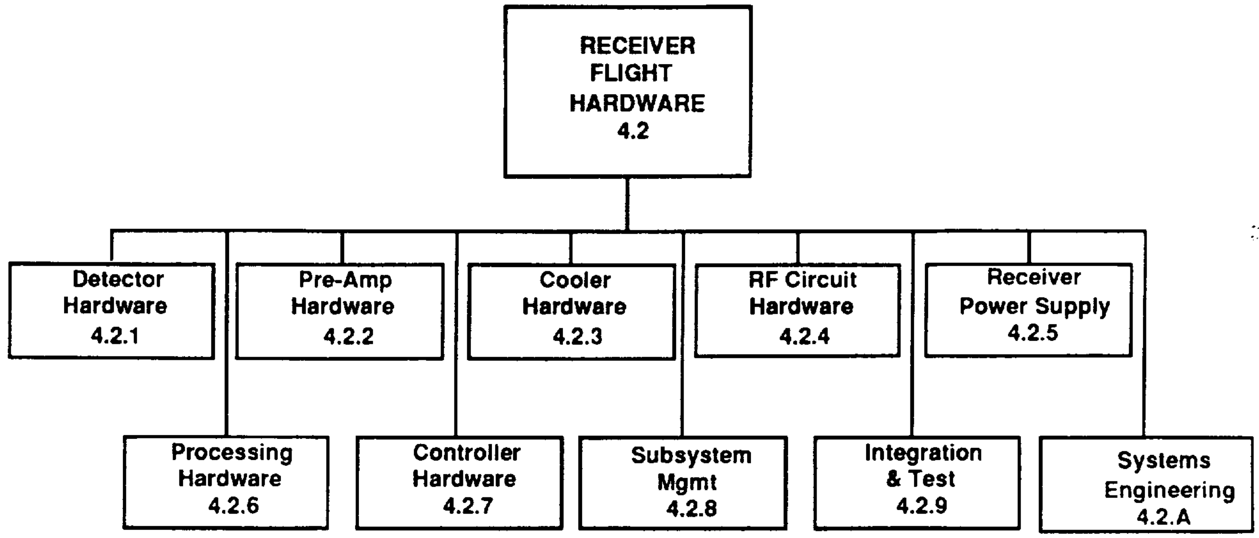
Perform and provide all of the engineering, manufacturing, materials, tooling, hardware and software, and services required to manage, procure, fabricate, assemble, verify, integrate, and ship the scan mechanism bearings, drive encoder, and tachometer. Conduct Telescope Subsystem acceptance testing. Provide verification support.

Perform component qualification testing in accordance with verification matrix.

4.1.2.2 *Scan Controls*

The scan controls consist of the electronics necessary to control the functions of the Optics, and include the scan mechanism drive and control electronics, the transmit/receive switch controller and synchronizer, the lag angle compensation controller, and sensor interface conditioning electronics.

Provide subcontractor technical monitoring and perform final functional testing for the scan electronics boxes.



4.2 Receiver Flight Hardware

This task involves the procurement of the various receiver assemblies and the complete receiver subsystem integration and test and all program management and system engineering.

4.2.1 *Detector Flight Hardware*

Procure flight qualified MCT detector assembly. This detector will be mounted by GE Astro. The detector will include connectors for bias voltage and input and output of the signal to the RF downconversion electronics. The detector assembly will also include the mounting hardware for attachment to the cooler cold finger as well as any required housing or baffling.

4.2.2 *Detector Pre-amp Hardware*

Build pre-amp capable of meeting the design requirements. This pre-amp will include connectors for the detector and RF circuits as well as any required housing and mounting brackets.

4.2.3 *Cooler Flight Hardware*

Procure flight qualified cooler for the detector and pre-amp. This hardware will include heat dissipation connectors, the cooler power supply and receiver controller/monitor data link interfaces .

4.2.4 *RF Circuit Flight Hardware*

Build flight qualified RF circuit boards. This circuitry will include the printed circuit boards, the chassis for containing the board or boards, the RF frequency synthesizer and all of the input and output electrical connectors. The RF frequency synthesizer will include data links to the receiver controller/monitor software.

4.2.5 *Power Supply Flight Hardware*

Build flight qualified power supply including detector bias voltage, cooler power supply, detector pre-amp power supply, RF electronics power supply and signal processing power supply. This power supply will include a data link to the receiver controller/monitor software.

4.2.6 *On-board Signal Processing Flight Hardware*

Build the flight qualified processing boards. This hardware will include all data links to the data buffer. RF electronics and the receiver controller/monitor. Also included will be electronic connectors for receiving power from the receiver power supply.

4.2.7 *Receiver Controller/Monitor Hardware*

This hardware and software will have data links to all of the receiver subsystem assemblies and will be integrated into the LAWS system controller.

4.2.8 *Management*

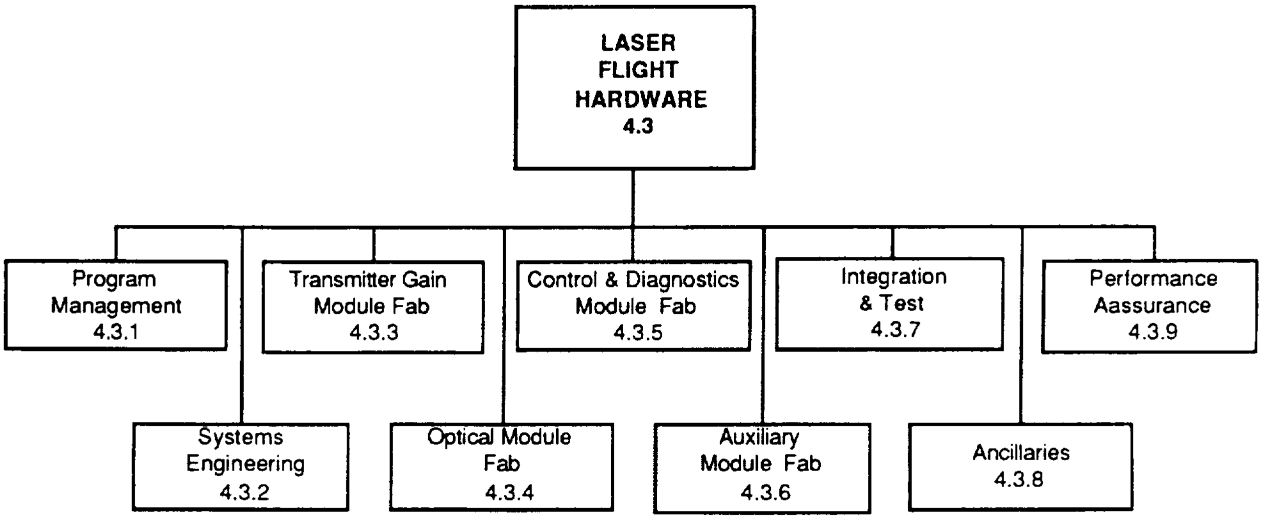
This task involves technical direction, customer support, subcontract management, reviews, and documentation and reporting for the entire receiver subsystem.

4.2.9 *Subsystem Integration and Test*

This task is to integrate all of the receiver assemblies and perform acceptance testing of the receiver subsystem..

4.2.A *Subsystem Engineering*

This task involves overall subsystem performance analysis and monitoring to ensure that all of the assembly and subsystem requirements and specifications are met during procurement. This includes verification of all reliability, survivability and safety issues for the flight hardware.



4.3 Laser Subsystem Flight Hardware

The Laser Subsystem has as its primary function the generation of two infrared beams: 1) the high power transmitter and 2) the local oscillator beams, respectively. The transmitter beam is provided to the Optics Subsystem, and the local oscillator beam is provided to the Receiver Subsystem. It derives its prime power from the platform via the sensor power distribution panel, and firing synchronization and power up commands from the sensor control computer. It distributes waste heat to the sensor cold plate and health, status and diagnostic information to the sensor control computer and signal processor, respectively. Mechanical interfacing to the sensor is implemented via two Modules: the Transmitter Gain and Optical Modules, respectively.

This task involves the fabrication, testing and integration into the sensor of the Laser Subsystem Flight model. All documentation, test plans, support equipment and spares are generated/developed/procured under this task.

4.3.1 *Program Management*

This WBS element includes technical direction, program planning and control, all documentation (reviews, manuals, data management and drawing package) and subcontract administration.

4.3.2 *System Engineering*

Experience gained during the testing of the qualification unit and/or operational performance of earlier flight units will be evaluated. The design of the Flight unit will be reviewed in light of this knowledge.

4.3.3 *Transmitter Gain Module Fabrication*

The transmitter laser Gain Module is manufactured under this task. It consists of the discharge region (incorporating the electrodes and preionizer), pulsed-power supply, the flow loop and fan, the heat exchanger, gas regenerator and the shell. Power and mechanical interfaces with the sensor and the heat exchanger interface with the cold plate are included.

4.3.4 *Optical Module Fabrication*

The optical module is fabricated under this task. It consists of all optical components and the athermal structure for their support. The interfaces with prime power, the control and diagnostics module and the sensor are also part of this task.

4.3.5 *Control and Diagnostics Module Fabrication*

The software packages and control voltage circuits required for the control and diagnostics module are written/fabricated. The control and diagnostics module accepts commands from the sensor host computer and feedback from the sensors in the optical module and in turn controls the operation of the laser and provides information to the host computer and signal processor.

4.3.6 *Auxiliary Module Fabrication*

Support equipment for ground-based operation of the flight unit during subsystem checkout and acceptance tests, sensor integration and pre-flight tests, storage and on-orbit deployment is built.

4.3.7 *Integration and Test*

Flight unit individual component assembly testing and their integration into the completed subsystem are accomplished under this task. Functional and acceptance tests are conducted and the test reports are prepared. Sensor integration and test support is included.

4.3.8 *Ancillaries*

Support equipment for ground-based operation of the flight unit during subsystem checkout and acceptance tests, during sensor integration and preflight tests, and during storage is built under this task.

Manufacture/procurement of flight-qualified spares, and shipment of the flight unit to the prime contractor are accomplished under this task.

4.3.9 *Performance Assurance*

Subsystem product assurance guidelines are applied to the fabrication of the Flight unit(s).

4.4 Structure Subsyslem Flight Hardware

Fabricate the main optical bench and mechanical support structure for subsystem interfaces and harness supports.

4.5 Thermal Subsystem Flight Hardware

Procure and test Heaters/temperature sensors and thermostats. Generate blanket and support patterns. Fabricate blankets and supports. Apply thermal coatings and inspect after application. Fabricate radiators as required. Fabricate laser fluid loop.

4.6 Electrical Subsystem Flight Hardware

Procure or fabricate power conditioning hardware. Manufacture electrical harnesses.

4.7 DMS Subsystem Flight Hardware

Fabricate the lidar system controller. Fabricate the data formatter and buffer.

4.8 ADS Subsystem Flight Hardware

Procure and test star trackers and inertial reference unit, as required (Space Station). Procure and test momentum compensation assembly.

4.9 Software Subsystem Flight Hardware

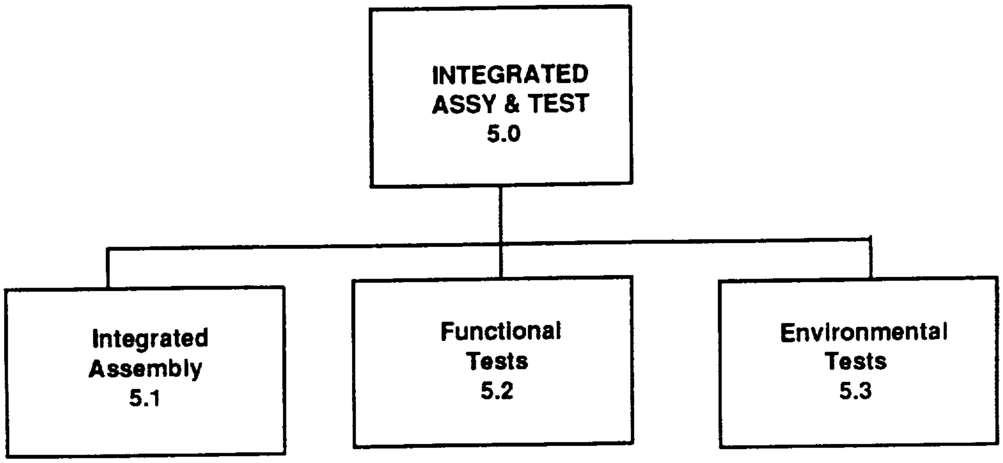
Install and test flight and ground software.

4.A Space Station Interface Flight Hardware

Support fabrication and testing of secondary structure required to accommodate LAWS instrument on the Space Station Freedom including thermal loop cold plate.

4.B JPOP Interface Flight Hardware

Support fabrication and testing of secondary structure required to accommodate LAWS instrument on the Japanese Polar Platform.



5.0 INTEGRATED ASSEMBLY & TEST

This element includes all LAWS assembly operations and all testing prior to the delivery of the instrument.

5.1 Integrated Assembly

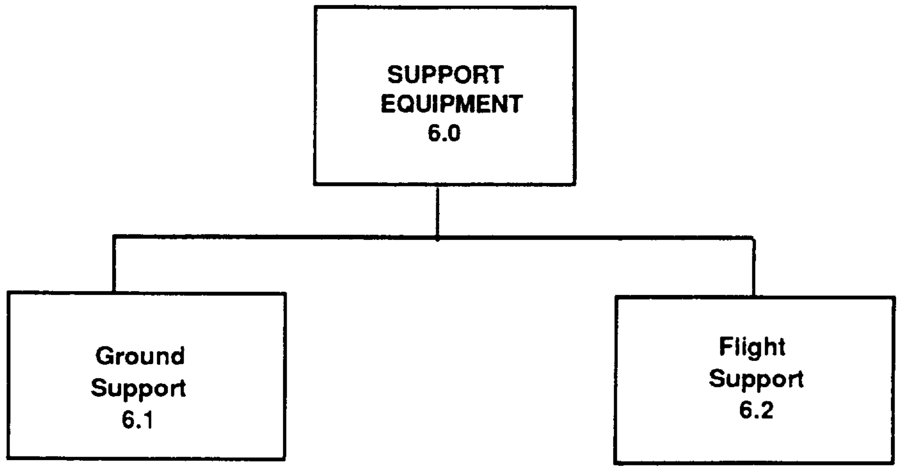
Assemble hardware for structure, electrical power, thermal control, attitude determination, and data management into integrated assembly with laser transmitter, receiver, and optical subsystems. Provide assembly drawings. Provide support to manufacturing during assembly operations. Provide configuration requirements. Provide required contamination control.

5.2 Functional Tests

Provide integration and test software generation and checkout. Provide data base generation. Plan, prepare, and checkout peripheral equipment required to support each specific test. Prepare test procedures for integration and functional tests. Perform electrical systems, end-to-end, and performance simulation tests.

5.3 Environmental Tests

Perform EMC/EMI, acoustic, thermal vacuum, orbital simulation, alignment, and flight system/ground system compatibility tests. Develop test procedures. Provide mechanical and electrical support during test operations.



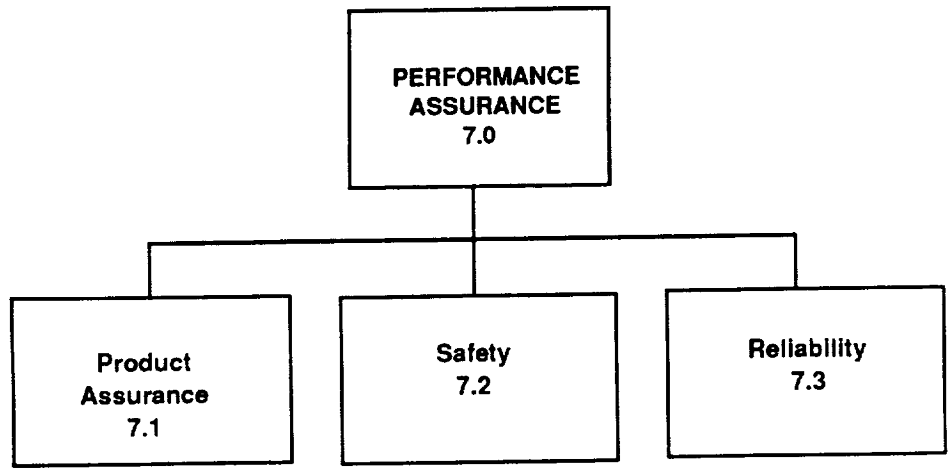
6.0 SUPPORT EQUIPMENT

6.1 Ground Support Equipment

Design, manufacture, and check out required GSE. GSE includes the I&T software development, the electrical GSE, the mechanical GSE, and the ground station equipment. Design and manufacture required contamination covers, bags, and shipping container.

6.2 Flight Support Equipment

Develop support software used for telemetry handling and data reduction. Provide hardware required for software operation and support.



7.0 PERFORMANCE ASSURANCE

The Performance Assurance element includes those activities which assure that the design meets all specified requirements and that the hardware has been correctly manufactured. This includes tasks to select and evaluate parts, materials and processes, define and assure contamination controls, and analyze design and reliability.

7.1 Product Assurance

Provide parts control, materials and processes control, contamination control, and quality assurance.

Parts control includes preparing and reviewing specification, providing defective parts procedures and requirements, and performing parts testing.

Materials and processes control includes generating data on shelf-life controlled items and monitoring and reviewing analysis and testing.

Contamination control includes establishing program cleanliness criteria, scheduling, monitoring, and reporting contamination levels, and performing contamination analyses.

Quality assurance includes drawing review identification and traceability, fabrication control, nonconformance control, configuration verification, software assurance, failure analysis and reporting, and receiving and shipping inspection.

7.2 Safety

Manage, implement, document, and analyze system safety requirements. Monitor safety requirements implementation. Conduct safety audits. Define safety plans. Perform hazard analyses and assessment and safety compliance reviews.

7.3 Reliability

Perform Failure Modes Effects Analysis. Assure selection and application of Parts, Materials, Processes and provide documentation for the parts stress analysis. Review and assemble worst case analysis and updates. Perform trend analysis. Prepare and maintain limited-life item list.